ISSN 1039-3218

The Distributions and Concentrations of Biomarkers for Sewage, Primary Producers and Bacteria in the Major Sediment Types of Port Phillip Bay

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Technical Report No. 17

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October 1994

EXECUTIVE SUMMARY

Port Phillip Bay has received urban and industrial waste products from the City of Melbourne for more than 150 years, but a sewerage system was not commissioned until 1897 when the Western Treatment Plant was established. Operation of this facility reduced the amount of raw sewage and industrial effluent entering the Bay considerably. Melbourne now has several other sewage treatment plants, however most of these do not discharge effluent into Port Phillip Bay. The Western Treatment Plant discharges 170,000 megalitres of secondary treated effluent into the Bay each year. The fate and impact of the sewage derived organic matter and nutrients on the ecology of the Bay are now under study through the Port Phillip Bay Environmental Study.

This study of organic biomarkers for sewage, primary production and bacteria in the sediments of Port Phillip Bay was designed to measure the relative and absolute contribution of these groups to the organic matter present. An additional strength of this approach is that the data can be integrated with and used to validate the models of water circulation and mixing that are being deeveloped for the Bay. Forty-six sediment samples were collected from the Bay in June 1993 and analysed for biomarkers. In April 1994 a further 9 sediment samples and eight water-column samples from selected rivers, creeks and drains were collected to help gain a better understanding of inputs into Port Phillip Bay.

Sewage derived biomarkers were present in low concentrations in most of the sediments analysed from within Port Phillip Bay. However, the concentrations of the faecal biomarker, coprostanol, in the sediments from the creeks, rivers and drains flowing into Port Phillip Bay reached levels similar to those measured from grossly polluted sediments near Sydney's Deep Ocean Outfalls. In addition, high concentrations of biomarkers for "ecologically significant" algal groups were found at these locations, which suggests that the high nutrient loads from these creeks and drains may have a localised impact on algal productivity.

Terrestrial input of higher plant matter was a minor source of organic matter. Rather the major source of organic carbon was the phytoplankton. This was an unexpected result since the waters of Port Phillip Bay are generally characterised as oligotrophic. Biomarkers for diatoms dominated both the sterol and fatty acid fractions. Other biomarkers for dinoflagellates, prymnesiophytes and eustigmatophytes were present in lower concentrations.

The markers for specific sulfate reducing bacteria (SRB) were most abundant in the sediments from the centre of Port Phillip Bay. The levels of SRB biomarkers are slightly elevated compared to open marine sediments, but the sediments are still oxic at the surface. The genus *Desulfobacter* appears to be the more dominant of the two sulfate reducing bacteria groups detected. The methods used here could successfully monitor changes in the microbial community particularly with regard to sulfate reducing bacteria.

To better understand the complex relationships between the physics, chemistry and biology of Port Phillip Bay, it would be useful to relate the biomarker data collected here with other data from the nutrient and toxicant data. Further work on water column samples from rivers and creeks under different flow regimes would enable an assessment of their relative contribution to the organic matter in the Bay and their impact on primary production. Similarly, further studies on the temporal and historical variations in biomarker concentrations in sediment cores would enable past blooms to be identified as well as variations in the sources of organic matter to the Bay.

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LIST OF ABBREVIATIONS USED IN TEXT

TOM	total organic matter
TOC	total organic carbom
C_{17}	denotes a carbon chain, 17 carbons in length
NSN	non-saponifiable neutral (lipid)
TEFA	total extractable fatty acid
PUFA	polyunsaturated fatty acid
PLFA	polar lipid fatty acid
SRB	sulfate reducing bacteria
DHA	docosahexaenoic acid (22:6ω3)
EPA	eicosapentaenoic acid (20:53)
i	iso branched chain
a	anteiso branched chain
c	*cis* geometry
t	*trans* geometry
cy	cyclopropane
GC	gas chromatography
GC-MS	gas chromatography-mass spectrometry
WTP	Western Treatment Plant at Werribee

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1.0 INTRODUCTION

1.1 Overview

Port Phillip Bay has received waste products from Melbourne's urban and industrial developments for more than 100 years. Concern about the possible effects this has had and will continue to have on the Bay has prompted a new environmental study. The Port Phillip Bay Environmental Study was commissioned by Melbourne Water, with practical research and data collection commencing in 1993.

The new study, which is managed by the CSIRO Institute of Natural Resources and Environment, plans to unravel the complex relationships between biology, chemistry and physics within Port Phillip Bay. Although the Bay has been the subject of many previous studies, the Port Phillip Bay Environmental Study will cross disciplines, to investigate relationships between tidal movements, aquatic life, nutrients and toxicants.

A major outcome of the study will be a series of computer models of the Bay. Such models will be used in future management with, for example, the model being used to indicate the effect of an increase or decrease in sewage inputs on the quality of the Bay.

This project was funded as part of Task N3.4 (Biomarkers in sediments) of the Port Phillip Bay Environmental Study. The aims of this project are to determine the distribution and concentrations of biomarkers (signature lipids) for sewage, primary producers and bacteria in the sediments of Port Phillip Bay. The biomarker approach is based on using organic marker compounds characteristic of specific flora, fauna, and bacteria, to determine the relative and absolute contribution of these groups to the organic matter present. Biomarkers, which can be accurately and reproducibly measured using chemical procedures, can be used where classical microscopic and microbiological methods fail (White et al. 1979).

A strength of the biomarker approach is that the data can be integrated with, and help validate, models of water circulation and mixing in the Bay. Unlike nutrients and metals which can arise from diverse sources, organic biomarkers can be related to more specific sources and even to specific events in the case of a spill of oil or chemicals etc. We have carried out similar studies with physical oceanographers (e.g. Sydney deep ocean outfalls and Devonport sewerage outfall in Bass Strait) in which the abundance of the faecal biomarker coprostanol was used to trace water transport and mixing.

A wide variety of biomarkers now exist that can, with appropriate methodological and interpretative skills, be readily used in environmental studies. A range of biomarkers exist for sewage, algae and bacteria as outlined below.

Sewage biomarkers: the principal biomarker is the faecal sterol coprostanol which is a direct measure of sewage. At sites strongly impacted by sewage it will also be possible to use fatty acid markers. An opportunity exists to examine other possible sewage markers which may be applicable in the Port Phillip Bay environment. Linear alkyl benzenes (LABs) are often found associated with sewage, however in Corio Bay, direct input of LABs from refinery effluent would mask any sewage derived LABs.

Primary productivity biomarkers: these include phytol (the side-chain of chlorophyll) and its degradation products including phytadienes; various sterols such as 24-methylenecholesterol and 24-methylcholesta-5,22E-dien-3-ol for diatoms, dinosterol and related 4-methyl sterols for dinoflagellates, including toxic species; additional sterols for other algal groups; unusual isoprenoid unsaturated hydrocarbons as biomarkers for specific diatoms; short-chain branched hydrocarbons as biomarkers for cyanobacteria and very long-chain (C_{37}-C_{39}) unsaturated ketones for prymnesiophyte contributions.

Bacterial biomarkers: fatty acids have proven to be amongst the most reliable biomarkers for many bacterial groups. Biomarkers exist for various sulfate reducing genera, however to our knowledge specific biomarkers are not currently known for other groups (nitrifiers and denitrifiers) requested in the call for proposals. -Hydroxy acids can also be used as biomarkers for a subset of the gram-negative bacteria present, as can particular double bond isomers of monounsaturated fatty acids (e.g. for methane oxidizers and other bacteria).

Other inputs: biomarkers also exist for higher plants (e.g. 24-ethylcholest-5-en-3-ol, long-chain alcohols and long-chain hydrocarbons). These can be used to examine terrestrial input from land run-off and atmospheric deposition. The hydrocarbon and hydroxy fatty acid distribution in sea grasses are very different from those in higher plants which enables differentiation between these two sources.

No data have been published on the distribution in Port Phillip Bay sediments of the various biomarkers proposed here. A number of studies, including work involving our group, have been carried out on the distribution of hydrocarbons in regions within Port Phillip Bay. The work being performed in this study is designed to test whether these biomarkers could be used successfully in the Port Phillip Bay area, and from this develop a set of chemical tools for monitoring future changes such as the populations of sulfate reducing bacteria and the levels of sewage contamination and to examine historical changes in organic carbon inputs.

1.2 Objectives

a) To determine spatial abundance of specific organic chemical biomarkers for sewage, primary producers and bacteria in Port Phillip Bay (PPB).

b) To investigate the potential for using biomarkers specific to major bacterial groups (including nitrifying, denitrifying and sulfate-reducing bacteria) to monitor the long-term trophic status of PPB.

We have presented our initial findings in a progress report submitted in March 1994 (O'Leary et al. 1994). In this report, data are reported for biomarker studies conducted for surface sediments collected from Port Phillip Bay during July 1993 and water column and sediments collected from the influent creeks during April 1994. These results will be pertinent to other tasks underway as part of the Port Phillip Bay Environmental Study, and could also be used in statistical analyses being carried out on the Port Phillip Bay database. The results of this study will also provide information required to assist in decisions to be made on the nature of future samples to be analysed as part of the biomarker task.

2.0 RESULTS

2.1 Sample Designation and Background

Site locations and other details are provided in Table 1 (a & b) and Figure 1. Sediment from 55 sites from Port Phillip Bay have been analysed for their organic matter, sterol, total fatty acid and polar lipid fatty acid compositions. These groups of compounds provide specific information on the composition of algal and bacterial communities and the relative proportion of terrestrial plant matter, sewage and other inputs into the Bay. In addition to the 32 sites originally proposed for analysis, 24 sediments and 8 water samples from the rivers, creeks and drains have also been analysed to gain further understanding of inputs into the Bay. The creek and drain samples were collected following completion of an interim report on this study (O'Leary et al. 1994).

In this final report it has been possible to present key biomarker data in map form. More detailed histogram plots of the various biomarkers can be found in the interim report (O'Leary et al. 1994). For the purpose of this study we have divided the Bay into 5 geographic zones which are illustrated in Figure 1. These zones reflect the distribution of sediment types in the Bay. The rivers, creeks and drains have been grouped together to enable the determination of input characteristics.

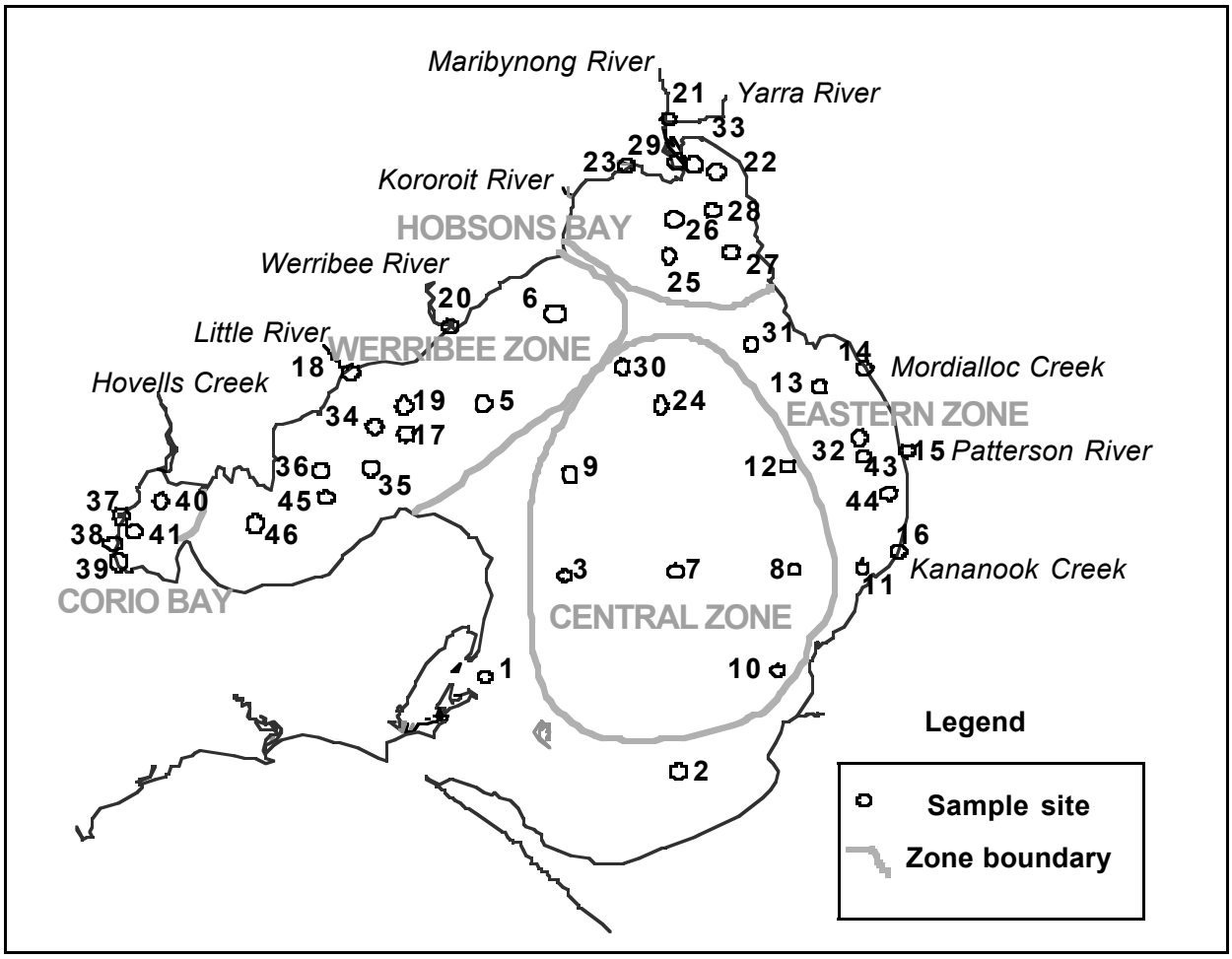

Figure 1. Location of sediment sampling sites in Port Phillip Bay, Victoria, Australia.

Table 1a. Port Phillip Bay sediment sample locations and bulk parameters**.**

Region	Site	Tox/Nut. Site	Latitude	Longitude	Dry Wt. ext (g)	% Water	% TOM*
Corio Bay	37	T7.03	38.1080	144.360	20.56	36.6	2.69
	38	T7.02	38.1280	144.358	32.72	27.3	1.43
	39	T7.01	38.1306	144.362	9.40	68.1	2.34
	40	T7.04	38.0966	144.406	10.09	69.9	2.58
	41	N3.01	38.1182	144.375	12.55	67.0	4.84
Werribee Zone	46	N3.04	38.1167	144.495	16.30	61.6	4.18
	17	T7.10	38.0533	144.638	35.30	28.9	0.50
	19**	T7.11	38.0296	144.643	28.72	22.9	0.76
	34	T7.08	38.0515	144.606	31.69	30.5	0.31
	35	T7.07	38.0783	144.602	26.83	30.2	0.78
	36	T7.06	38.0783	144.563	15.48	50.6	1.93
	45	T7.05	38.0977	144.563	14.89	49.8	2.43
	5	T7.13	38.0350	144.720	47.60	21.3	0.23
	6	N3.12	37.9683	144.794	43.97	21.6	0.66
Hobsons Bay Zone	22	T7.24	37.8656	144.941	34.27	18.9	0.23
	29	T7.22	37.8617	144.912	13.96	58.9	4.32
	33	T7.21	37.8700	144.920	31.93	31.1	3.46
	25	T7.18	37.9288	144.902	19.81	54.6	2.40
	26	T7.19	37.9021	144.905	18.31	48.2	3.22
	27	T7.26	37.9258	144.962	29.72	18.5	0.54
	28	T7.25	37.8918	144.947	34.39	20.6	0.54
Central Zone	1	T7.40	38.2317	144.712	44.02	31.1	1.00
	3	T7.41	38.1583	144.795	4.65	86.9	8.50
	7	T7.37	38.1583	144.901	13.37	73.9	6.46
	8**	T7.36	38.1583	145.013	16.32	63.7	3.45
	9	T7.14	38.0844	144.801	16.12	70.6	6.39
	10	T7.38	38.0533	144.638	35.51	54.7	1.76
	24	T7.16	38.0397	144.892	6.37	77.4	5.34
	30	T7.15	38.0091	144.855	7.15	75.4	5.33
Eastern Zone	2	T7.39	38.3067	144.898	24.82	40.5	1.88
	11	T7.33	38.1548	145.079	35.38	30.4	1.08
	13	T7.28	38.0250	145.044	45.30	19.8	0.92
	31	T7.27	37.9926	144.979	13.83	61.0	4.43
	32	N3.18	38.0642	145.083	28.27	32.0	1.45
	43	T7.31	38.0777	145.083	27.13	27.8	1.04
	44	N3.2	38.1045	145.104	32.32	20.9	0.52
Creeks	14	T7.29	38.0120	145.084	47.21	21.6	0.35
	15	T7.30	38.0712	145.126	16.06	55.7	3.60
	16	T7.32	38.1475	145.117	34.87	27.9	1.11
	18	T7.09	38.0067	144.590	25.59	41.3	2.07
	20	T7.12	37.9750	144.684	11.29	69.3	6.94
	21	T7.23	37.8234	144.903	10.09	72.3	8.64
	23	T7.20	38.1280	144.358	22.33	41.87	3.10

* Weight Loss on ignition at 450^{O}C ** 3 replicates taken.

Table 1b. Influent Creek water column and sediment sample locations and bulk parameters.

			Sediments			Water
Region	Site	Position	Dry Wt. ext. (g)	%TOM	% Water	Vol filtered (L)
WTC outfall	47	Drain servicing 115e, 55e, 25w & 85wB	27.96	1.88	33.1	0.6
Elwood Canal	49	Barkly St, Elwood	21.77	8.97	44.9	4.8
Mordialloc Creek #1	50	Park St, Mordialloc	14.07	12.12	64.8	4.8
Mordialloc Creek #2	51	Cnr Boundary & Wells Rd, Aspendale	49.96	2.17	26.2	5.0
Kananook Creek.	52	Seaford Rd, Seaford	46.84	3.69	27.4	5.2
Werribee River	53	Mouth	27.07	2.68	34.8	8.0
Werribee River #2	54	Near Princes Highway	15.39	5.50	55.5	6.0
Hovells Creek	55	Near Mouth	21.08	2.47	37.7	4.0
Patterson River	56	Tennyson St, Carrum	38.38	1.38	24.5	none

2.2 Total Organic Matter

Organic matter content of sediments from Port Phillip Bay have been analysed by loss on ignition at 450^0C for this report. Organic matter comprised between 0.2% to 8.5% of the sediments (Table 1a, Figure 2). The Central Zone had relatively high quantities of organic matter up to 8.5%. This suggests that deposition and accumulation of organic material occurs principally in the Central Zone relative to other zones. Organic matter accounted for 1.4% to 4.8% of the sediments in Corio Bay and 4.2% in the Geelong Arm indicating that deposition is also occurring in these regions (Figure 2). The Werribee Zone typically had organic matter values < 2%, showing that mixing occurs in this region and the finer sediment and organic detritus is winnowed out. The rest of Port Phillip Bay seems to be characterised by sandy sediments except for some patches of finer sediments notably in the western portion of the Hobsons Bay Zone.

The sediments collected from the rivers and creeks were relatively rich, containing between 1.1% and 12.2% organic matter, with the exception of one site from Mordialloc Creek which only had 0.35% organic matter (Tables 1a and 1b).

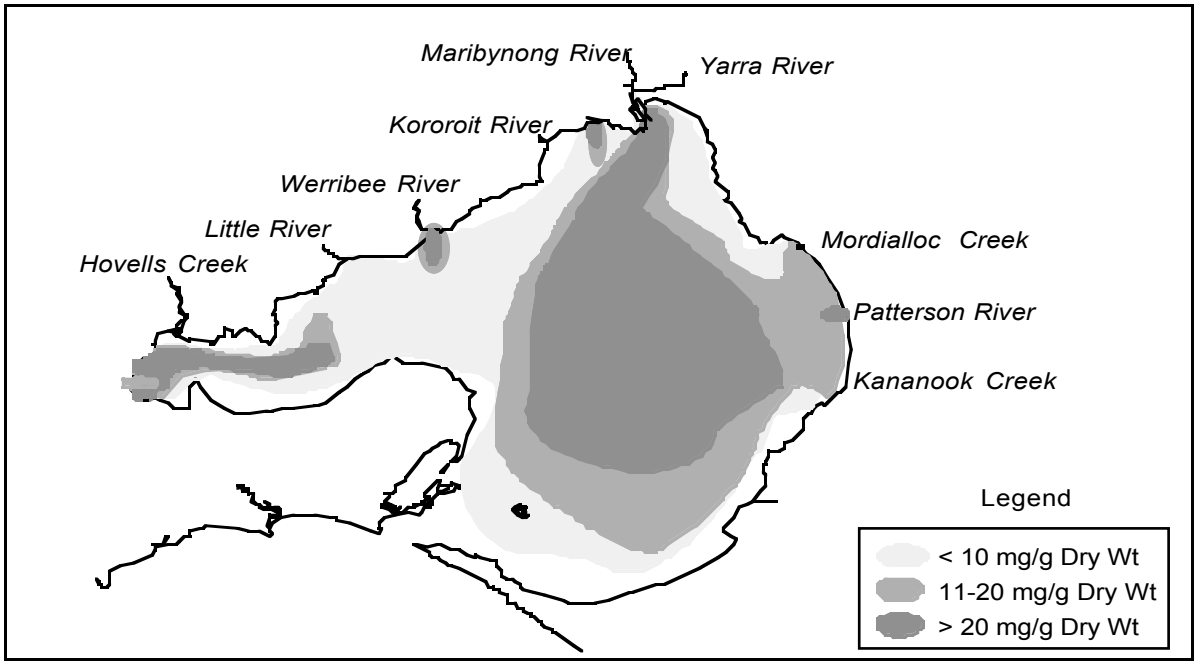

Figure 2. Organic matter content. This distribution indicates that organic matter is most abundant in the Central Zone and the rivers and creeks are sources of organic matter.

2.3 Compound classes

Three major compound classes (sterols, fatty acids and polar lipid fatty acids) were studied in order to determine the sources of organic matter in the Port Phillip Bay sediments (Tables 2-5). There are two minor compound classes, long-chain alkenones and diols, that also provide important biomarker information (Table 3). These compounds are found in the non-saponifiable neutral (NSN) fraction along with the sterols. Sterols and total extractable fatty acids (TEFA) are derived from detrital material in addition to living cells. Sterols are rarely present in bacteria and generally are derived from eukaryotic sources only. In contrast, PLFA are found in the cell membranes of viable eubacteria and other organisms and are rapidly degraded upon cell death. The concentration of PLFA is generally much lower than that measured for the TEFA (Tables 4 and 5) indicating that detritus including sewage-derived, bacterial, algal and terrestrial material is the predominant source of organic matter in Port Phillip Bay sediments.

2.3.1 Sterols, long-chain alkenones and diols

Sterols are important membrane components in eukaryotic organisms and contain structural features which can be unique to specific groups of organisms. Sterol compositional data are given in Table 2. Representative chromatograms are presented in Figure 3. The concentration of total sterols in Port Phillip Bay sediments ranged from a minimum of 0.6 g g^{-1} (dry weight) in sandy sediment east of Werribee to a maximum of 39.2 g g^{-1} (dry weight) in fine silty sediment in the Central Zone (Table 2).

The concentration of total sterols in sediments of influent creeks was generally higher than in bay sediments and ranged from 22.8 - 148 g g^{-1} (dry weight) except for the mouth of the Mordialloc Creek which contained only 2 g g^{-1}. These concentrations represented 5 - 25% of the corresponding total fatty acid concentrations. In some cases there were considerable variations within zones, but the general trend observed for the concentration of total sterols on a dry weight basis was: Creeks Corio Bay Central Zone Werribee Hobsons Bay Eastern Zone.

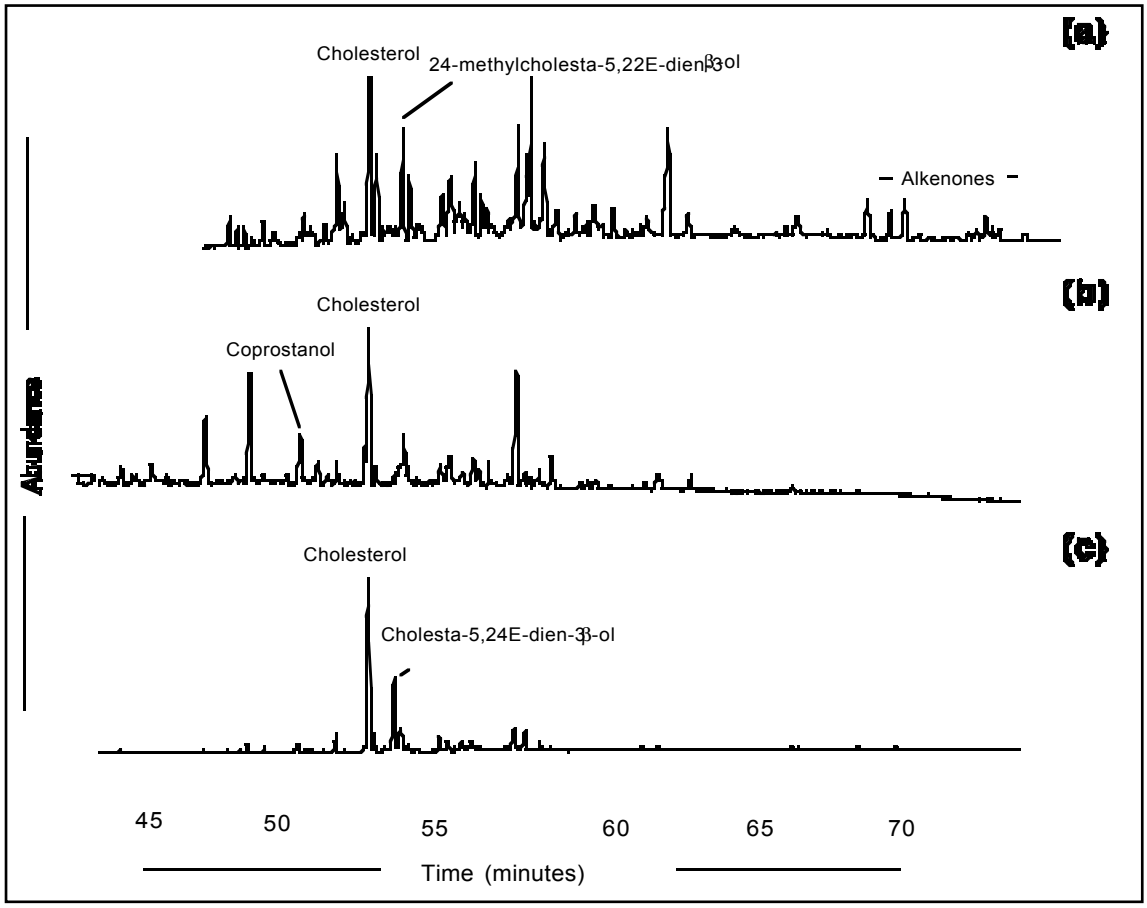

Figure 3. Partial chromatogram of several NSN fractions. Trace (a) from site #7 in the Central Zone shows the contribution of 24-methylcholesta-5,22E-dien-3-ol, a marker for the presence of diatoms. This trace also contains alkenones which are markers for the presence of prymnesiophytes. Trace (b) from Kananook Creek shows the elevated level of the faecal biomarker coprostanol. Trace (c) from the Werribee River illustrates the contribution of cholesta-5,24E-dien-3-ol. This sterol is found in high concentrations in diatoms from the genus *Rhizosolenia* and a few other species.

Table 2a. Sterol content and composition for Port Phillip Bay sediments: Corio Bay and Werribee Zone.

		Percent Composition													
		Corio Bay					Werribee								
Sterol	Trivial name	37	38	39	40	41	46	17	19	34	35	36	45	5	6
24-norcholesta-5,22E-dien-3β-ol		0.3	-	1.5	-	1.2	0.9	1.1	0.8	1.1	1.0	0.8	1.6	1.8	1.3
24-nor-5α-cholest-22E-en-3β-ol		-	0.2	0.6	1.3	1.1	0.6	0.4	0.4	0.6	0.9	1.1	0.4	0.8	0.9
5β-cholestan-3β-ol	coprostanol	-	2.7	0.8	1.4	0.6	1.3	1.3	1.4	1.0	2.1	1.4	0.5	0.6	1.3
5β-cholestan-3α-ol	epi-coprostanol	0.3	0.3	1.6	0.5	1.1	0.2	-	-	0.3	0.5	0.2	0.2	-	0.7
27-nor-24-methylcholesta-5,22E-dien-3β-ol		-	-	0.9	0.8	1.1	0.8	1.2	1.0	0.6	0.7	0.9	1.0	1.2	1.0
cholesta-5,22E-dien-3β-ol	trans-22-dehydrocholesterol	2.6	2.8	9.1	6.4	4.9	6.4	8.2	6.5	8.0	6.5	6.8	7.7	7.7	6.0
5α-cholest-22E-en-3β-ol	trans-22-dehydrocholestanol	0.2	-	0.3	1.1	0.8	1.0	1.0	0.9	0.9	1.2	1.4	0.8	1.3	0.5
cholest-5-en-3β-ol	cholesterol	29.4	40.4	37.3	21.9	26.1	33.9	28.2	29.0	32.3	26.3	28.8	36.9	19.3	27.7
5α-cholestan-3β-ol	cholestanol	4.1	3.6	3.3	5.4	5.4	5.1	3.3	4.5	5.5	6.3	5.5	3.4	4.9	4.4
cholesta-5,24-dien-3β-ol	desmosterol	4.9	8.6	2.8	2.1	3.8	3.1	3.2	3.5	2.7	1.2	2.7	3.0	2.1	1.1
24-methylcholesta-5,22E-dien-3β-ol	diatomsterol	7.7	3.5	11.4	15.2	13.7	11.4	15.0	14.2	14.3	12.1	12.4	13.9	14.1	15.5
24-methyl-5α-cholest-22E-en-3β-ol	diatomstanol	2.2	2.3	2.4	4.6	4.7	2.5	2.1	2.4	2.7	4.1	3.1	1.7	2.1	3.4
5α-cholest-7-en-3β-ol	^{7}-cholesterol	2.1	0.6	1.6	2.3	1.4	0.8	0.4	0.3	0.4	0.8	0.9	0.9	-	-
24-methylcholesta-5,24(28)-dien-3β-ol	24-methylenecholesterol	4.3	7.6	5.7	4.8	4.0	4.8	4.6	4.3	4.9	3.7	4.4	6.0	5.5	3.9
24-methylcholest-5-en-3β-ol	24-methylcholesterol	6.4	4.9	4.8	6.1	4.5	4.7	4.1	4.9	3.6	5.3	4.6	3.9	6.5	5.7
24-methyl-5α-cholestan-3β-ol	24-methylcholestanol	0.4	0.5	-	1.2	1.5	1.1	0.7	1.5	0.9	1.5	1.2	0.7	0.6	0.5
23,24-dimethylcholesta-5,22E-dien-3β-ol		2.0	-	1.4	2.5	1.7	1.6	3.0	2.5	1.8	2.5	1.6	0.6	1.7	3.3
24-ethylcholesta-5,22E-dien-3β-ol		6.5	3.7	2.4	3.3	3.7	3.8	5.7	5.9	4.1	4.8	3.9	3.4	7.7	5.4
24-ethyl-5α-cholest-22E-en-3β-ol		-	1.2	0.7	1.3	1.5	1.2	1.2	1.1	1.1	1.9	1.4	1.0	1.1	1.6
24-ethylcholest-5-en-3β-ol	24-ethylcholesterol	*20.7	10.0	*6.3	*10.2	*9.1	7.2	*9.3	7.9	7.1	*8.7	*9.0	*6.7	12.4	7.8
24-ethylcholesta-5,24(28)E-dien-3β-ol	fucosterol		1.1				1.4		0.6	0.8				1.7	1.3
24-ethyl-5α-cholestan-3β-ol	24-ethylcholestanol	†2.8	2.2	†2.8	†4.8	†4.4	2.1	†3.8	2.3	1.7	†4.6	†4.6	†3.7	1.6	1.6
24-ethylcholesta-5,24(28)Z-dien-3β-ol	isofucosterol		2.0				1.7		2.1	1.6				2.7	1.8
4,23,24-trimethyl-5α-cholest-22E-en-3β-ol	dinosterol	3.2	1.8	2.3	2.9	3.9	2.6	2.2	1.9	2.1	3.6	3.3	2.0	2.7	3.5
Total sterols g/g dry wt.		31.8	11.5	28.7	10.8	14.4	19.4	4.7	2.5	5.9	3.4	10.8	18.6	0.6	1.9
coprostanol ng/g dry wt.		-	314	216	148	90	258	60	35	60	69	146	96	4	24
coprostanol g/g of organic matter		-	22.0	9.2	5.7	1.9	6.2	11.9	5.0	19.5	7.7	7.6	3.9	1.6	3.6

* combined value includes small amounts of fucosterol

† combined value includes small amounts of isofucosterol

Table 2b. Sterol content and composition for Port Phillip Bay sediments: Hobsons Bay and Central Zone.

		Percent Composition															
		Hobsons Bay			Central Zone ---												
Sterol	Trivial name	22	29	33	25	26	27	28	1	3	7	8	9	10	24	30	
24-norcholesta-5,22E-dien-3β-ol		0.9	2.1	1.3	2.3	1.9	1.4	1.2	2.6	2.5	2.1	2.0	2.2	2.2	2.0	2.7	
24-nor-5α-cholest-22E-en-3β-ol		-	0.5	1.0	1.0	0.9	0.9	0.6	0.8	1.0	1.5	1.6	0.7	1.4	2.0	1.5	
5β-cholestan-3β-ol	coprostanol	1.6	1.7	1.4	1.2	1.6	1.4	1.5	1.2	1.4	1.1	1.0	0.4	1.3	1.4	1.0	
5β-cholestan-3α-ol	epi-coprostanol	-	-	0.2	0.4	0.1	0.3	0.1	0.6	0.3	0.7	0.3	-	0.1	1.2	0.9	
27-nor-24-methylcholesta-5,22E-dien-3β-ol		0.4	1.3	0.5	1.2	0.9	1.1	0.9	1.6	4.7	1.6	1.8	0.9	1.7	1.7	2.0	
cholesta-5,22E-dien-3β-ol	trans-22-dehydrocholesterol	5.0	7.3	5.5	7.4	7.4	5.8	6.0	7.8	5.8	6.5	6.9	10.3	8.2	6.6	7.5	
5α-cholest-22E-en-3β-ol	trans-22-dehydrocholestanol	0.5	0.8	0.8	0.8	1.1	0.4	0.5	2.3	1.3	2.1	2.4	0.9	1.9	1.7	1.0	
cholest-5-en-3β-ol	cholesterol	30.5	25.4	26.1	33.0	39.0	34.7	32.1	28.5	20.5	13.9	20.8	44.7	25.3	12.6	21.7	
5α-cholestan-3β-ol	cholestanol	4.0	4.0	5.7	3.3	4.2	4.0	3.6	3.9	3.8	5.7	6.1	2.3	5.0	5.4	4.3	
cholesta-5,24-dien-3β-ol	desmosterol	1.9	4.3	4.3	1.9	1.4	5.4	2.7	1.6	1.5	1.2	0.9	1.7	2.0	2.1	2.2	
24-methylcholesta-5,22E-dien-3β-ol	diatomasterol	14.0	11.0	6.6	12.4	9.7	12.5	14.4	11.8	12.7	10.6	10.7	7.5	11.3	11.0	12.1	
24-methyl-5α-cholest-22E-en-3β-ol	diatomstanol	2.0	2.7	4.4	2.4	3.4	2.5	2.2	2.7	2.3	5.4	4.4	1.8	4.3	4.6	3.3	
5α-cholest-7-en-3β-ol	^{7}-cholesterol	0.4	2.6	3.6	1.2	0.9	1.3	1.1	-	-	1.1	0.9	0.7	1.2	2.0	1.2	
24-methylcholesta-5,24(28)-dien-3β-ol	24-methylenecholesterol	4.8	5.6	4.1	3.8	3.0	3.9	5.3	4.2	4.9	4.9	3.1	2.9	3.6	3.8	4.3	
24-methylcholest-5-en-3β-ol	24-methylcholesterol	4.8	4.6	4.4	4.0	5.7	4.9	4.6	4.6	4.4	5.8	5.3	2.8	4.2	5.2	4.5	
24-methyl-5α-cholestan-3β-ol	24-methylcholestanol	0.7	0.4	1.5	0.5	0.9	0.5	0.5	1.3	0.2	-	2.0	0.6	0.8	2.0	1.1	
23,24-dimethylcholesta-5,22E-dien-3β-ol		2.3	1.3	2.5	1.1	1.0	2.0	1.8	1.5	1.3	0.9	1.3	1.0	1.3	1.8	1.4	
24-ethylcholesta-5,22E-dien-3β-ol		6.9	4.4	3.7	3.6	2.2	3.7	4.7	4.1	4.7	5.8	4.7	2.9	3.9	5.4	4.6	
24-ethyl-5α-cholest-22E-en-3β-ol		1.1	0.9	1.1	1.3	1.0	0.8	1.1	1.8	2.6	3.2	2.8	1.5	2.0	3.1	1.8	
24-ethylcholest-5-en-3β-ol	24-ethylcholesterol	*11.7	9.7	*11.1	*9.6	*7.6	8.4	*8.8	8.8	12.0	10.6	9.1	*8.1	*9.9	*11.4	10.6	
24-ethylcholesta-5,24(28)E-dien-3β-ol	fucosterol		0.7				0.5		0.9	1.2	1.4	0.6					
24-ethyl-5α-cholestan-3β-ol	24-ethylcholestanol	†4.4	2.3	†5.6	†4.3	†3.2	0.4	†3.1	2.0	2.0	4.4	4.6	†3.7	†5.1	†7.3	5.6	
24-ethylcholesta-5,24(28)Z-dien-3β-ol	isofucosterol		2.7				0.4		2.5	4.6	3.4	1.7					
4,23,24-trimethyl-5α-cholest-22E-en-3β-ol	dinosterol	2.1	3.8	4.5	3.2	2.8	2.9	3.3	3.0	4.5	6.3	5.1	2.6	3.3	5.6	4.5	
Total sterols g/g dry wt.		1.1	20.6	2.9	8.1	12.3	1.6	2.2	2.8	39.2	12.8	7.1	13.8	5.7	9.2	9.3	
coprostanol ng/g dry wt.		18	351	41	98	202	22	32	33	549	142	69	54	72	126	91	
coprostanol g/g of organic matter		7.8	8.1	1.2	4.1	6.3	4.0	6.0	3.3	6.5	2.2	2.8	1.4	4.1	2.4	1.7	

* combined value includes small amounts of fucosterol

† combined value includes small amounts of isofucosterol

Table 2c. Sterol content and composition for Port Phillip Bay sediments: Esatern Zone and Creeks.

		Percent Composition													
		Eastern Zone							Influent Creeks						
Sterol	Trivial name	2	11	13	31	32	43	44	14	15	16	18	20	21	23
24-norcholesta-5,22E-dien-3β-ol		1.8	1.3	1.2	3.1	1.8	1.9	1.3	0.4	0.5	0.4	0.2	0.4	1.1	0.4
24-nor-5α-cholest-22E-en-3β-ol		0.6	1.5	0.3	1.7	1.5	1.3	0.3	-	-	-	-	-	1.0	1.1
5β-cholestan-3β-ol	coprostanol	1.3	1.8	0.7	1.3	0.9	1.0	0.4	2.6	4.0	8.7	3.0	1.7	3.8	2.4
5β-cholestan-3α-ol	epi-coprostanol	0.3	0.3	-	0.3	1.5	0.7	-	-	-	0.4	0.1	-	-	0.3
27-nor-24-methylcholesta-5,22E-dien-3β-ol		2.6	1.0	0.5	1.5	1.6	1.4	1.2	1.5	0.4	-	0.2	0.3	-	-
cholesta-5,22E-dien-3β-ol	trans-22-dehydrocholesterol	6.3	6.8	5.0	7.7	7.6	5.9	9.0	5.1	4.4	3.2	11.1	4.0	4.3	6.2
5α-cholest-22E-en-3β-ol	trans-22-dehydrocholestanol	0.8	0.9	0.2	1.0	0.6	0.8	0.4	0.7	0.5	-	0.8	0.3	0.4	0.5
cholest-5-en-3β-ol	cholesterol	29.5	25.9	40.2	23.9	20.4	28.0	40.6	25.3	31.1	27.0	43.2	43.5	31.1	30.2
5α-cholestan-3β-ol	cholestanol	2.8	4.2	1.6	4.2	4.2	4.0	1.8	4.3	6.1	2.9	4.8	3.2	3.8	5.6
cholesta-5,24-dien-3β-ol	desmosterol	10.9	2.8	11.4	1.4	2.0	1.4	0.6	4.4	3.6	1.7	3.6	14.9	2.4	5.9
24-methylcholesta-5,22E-dien-3β-ol	diatomsterol	10.9	12.0	13.5	14.3	17.9	15.3	15.9	12.5	7.3	8.1	8.2	5.4	6.5	8.5
24-methyl-5α-cholest-22E-en-3β-ol	diatomstanol	2.1	4.4	0.9	3.4	3.6	3.4	0.9	3.2	3.0	1.6	2.1	1.6	3.0	3.6
5α-cholest-7-en-3β-ol	7-cholesterol	0.3	1.4	0.6	1.4	1.8	1.4	0.4	0.5	1.5	1.3	0.4	0.5	1.9	1.5
24-methylcholesta-5,24(28)-dien-3β-ol	24-methylenecholesterol	6.3	4.1	3.2	4.4	4.9	4.9	5.2	3.2	4.0	2.6	2.0	3.1	4.5	3.7
24-methylcholest-5-en-3β-ol	24-methylcholesterol	4.2	4.5	4.5	4.2	4.2	4.9	5.0	4.4	4.7	6.0	3.5	2.8	5.5	4.4
24-methyl-5α-cholestan-3β-ol	24-methylcholestanol	-	0.5	0.2	0.9	-	0.6	0.5	1.1	1.0	-	0.9	0.7	1.1	0.7
23,24-dimethylcholesta-5,22E-dien-3β-ol		0.9	3.3	1.4	2.1	2.6	2.5	4.1	5.2	2.6	1.6	6.7	2.5	2.5	2.9
24-ethylcholesta-5,22E-dien-3β-ol		3.1	5.0	4.1	4.8	5.1	4.8	3.3	6.2	6.1	6.6	2.7	2.2	4.1	5.1
24-ethyl-5α-cholest-22E-en-3β-ol		1.6	1.7	0.6	1.7	1.5	1.4	0.4	1.4	0.8	1.7	0.2	0.4	0.4	1.0
24-ethylcholest-5-en-3β-ol	24-ethylcholesterol	7.0	*9.0	*6.7	*10.0	*9.3	*8.7	*5.8	*12.5	13.8	*20.6	3.7	4.3	*15.2	8.3
24-ethylcholesta-5,24(28)E-dien-3β-ol	fucosterol	0.5								3.0		-	0.7		1.2
24-ethyl-5α-cholestan-3β-ol	24-ethylcholestanol	1.7	†3.9	†2.2	†4.3	†3.4	†3.1	†1.0	†3.5	0.4	†3.0	1.0	1.1	†4.7	1.9
24-ethylcholesta-5,24(28)Z-dien-3β-ol	isofucosterol	2.2								0.3		0.2	3.7		0.9
4,23,24-trimethyl-5α-cholest-22E-en-3β-ol	dinosterol	2.5	3.8	0.9	2.8	3.7	2.5	1.8	1.8	0.9	2.5	1.4	2.5	2.5	3.6
Total sterols g/g dry wt.		8.5	3.4	1.9	6.8	3.6	2.7	6.4	2.0	22.8	23.8	58.5	148.0	39.5	24.1
coprostanol ng/g dry wt.		114	62	13	88	32	26	26	53	917	2077	1754	2584	1495	585
coprostanol g/g of organic matter		6.1	5.7	1.5	2.0	2.2	2.5	5.1	15.0	25.5	187.1	84.8	37.2	17.3	18.9

* combined value includes small amounts of fucosterol

† combined value includes small amounts of isofucosterol

Table 2d. Sterol content and composition for river and creek water column and sediment.

		Percent Composition																
		Water Column								Sediments								
Sterol	Trivial name	47	49	50	51	52	53	54	55	47	49	50	51	52	53	54	55	56
5-cholestan-3-ol	coprostanol	4.6	1.1	14.2	6.6	0.5	0.7	-	0.7	2.7	0.7	-	-	1.3	1.1	0.3	0.7	0.5
5-cholestan-3-ol	epi-coprostanol	0.4	0.3	3.9	-	-	0.3	-	0.5	0.9	0.1	-	-	-	0.4	-	0.6	-
27-nor-24-methylcholesta-5,22E-dien-3-ol		-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
cholesta-5,22E-dien-3-ol	trans-22-	2.0	4.2	2.9	11.7	2.2	4.8	4.8	14.8	4.3	8.4	14.2	10.1	10.5	5.1	3.1	10.9	12.6
cholest-5-en-3-ol	cholesterol	22.0	35.3	23.8	33.0	16.1	36.1	18.5	28.0	42.5	17.9	18.7	37.8	10.3	54.9	10.6	30.9	32.4
5-cholest-3-ol	cholestanol + C28 alcohol	9.0	5.6	7.6	7.7	4.0	7.0	7.8	0.8	7.4	11.3	8.3	8.8	10.6	5.1	5.8	6.3	4.5
cholesta-5,24-dien-3-ol	desmosterol	0.6	0.9	0.3	-	0.6	0.6	-	1.1	4.2	1.5	0.7	-	1.1	1.8	-	-	-
24-methylcholesta-5,22E-dien-3-ol	diatomsterol	5.9	4.4	6.4	5.0	6.8	12.8	10.1	8.3	7.7	5.4	6.5	5.9	3.6	7.7	10.5	6.8	16.0
24-methyl-5-cholest-22E-en-3-ol	diatomstanol	-	-	-	-	-	-	-	-	0.8	-	-	-	-	-	-	-	-
5-cholest-7-en-3-ol	7-cholesterol	1.2	2.4	0.6	-	0.7	1.4	0.7	3.9	1.9	0.8	-	-	0.6	0.8	0.3	2.7	1.1
24-methylcholesta-5,7,22-trien-3-ol	ergosterol	-	-	-	-	-	-	-	-	-	-	-	-	1.5	0.6	1.1	-	-
24-methylcholesta-5,24(28)-dien-3-ol	24-methylenecholesterol	1.3	4.6	7.2	2.8	3.8	6.7	3.6	4.5	5.5	4.2	3.7	-	1.5	1.9	5.1	2.3	3.7
24-methylcholest-5-en-3-ol	24-methylcholesterol	4.1	8.4	-	3.0	5.7	3.3	7.8	4.9	3.4	4.7	7.6	5.4	3.6	3.8	3.2	5.7	6.5
5-ethylcholestanol		3.3	-	3.3	-	-	-	-	-	-	-	-	-	-	-	-	-	-
24-methyl-5-cholestan-3-ol	24-methylcholestanol	0.8	0.8	0.2	0.9	-	0.6	0.5		2.5	-	-	-	0.9	-	0.5	0.5	0.9
23,24-dimethylcholesta-5,22E-dien-3-ol		0.9	0.5	-	-	-	1.0	0.6	3.8	3.0	1.4	3.0	-	0.7	1.7	1.9	3.8	1.2
24-ethylcholesta-5,22E-dien-3-ol		23.2	3.5	6.9	7.7	1.4	3.3	8.5	5.8	4.6	3.4	5.8	4.1	5.7	3.2	2.4	5.7	5.1
23,24 dimethyl-5-cholest-22E-en-3-ol		-	1.0	-	-	1.0	-	-	-	-	-	-	-	-	-	-	-	-
24-methyl-5-cholest-7-en-3-ol	ergost-7-enol	2.3	-	4.4	2.3		-	-	-	-	-	0.7	-	3.5	-	-	-	1.2
4,24-dimethyl-5-cholest-22E-en-3-ol		-	-	-	-	1.3	-	-	-	-	-	-	-	-	-	-	-	-
4,24-dimethyl-5-cholesta-5,7-dien-3-ol		-	-			1.0	-	-	-	-	-	-	-	-	-	-	-	-
24-ethylcholest-5-en-3-ol	24-ethylcholesterol *	14.3	12.1	15.4	14.9	46.2	11.5	22.5	13.9	6.1	24.7	23.0	20.7	28.3	8.7	44.4	18.9	10.6
24-ethylcholesta-5,24(28)E-dien-3-ol	fucosterol	2.1	4.6	2.9	3.5	6.6	9.2	11.5	5.2	1.2	8.1	4.8	5.8	11.8	2.0	3.4	2.6	3.6
23,24-dimethyl-5-cholestan-3-ol		-	-	-	-	-	-	-	-	-	-	-	-	-	-	3.6	1.1	-
24-ethyl-5-cholestan-3-ol	24-ethylcholestanol †	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
4,23,24-trimethyl-5-cholest-22E-en-3-ol	dinosterol	-	10.3	-	-	1.8	0.8	2.5	1.7	0.7	7.2	-	-	-	1.1	-	0.6	-
24-ethyl-5-cholest-7-en-3-ol		2.0	-	-	1.7	-	-	-	0.9	0.5	-	2.5	1.4	4.5	-	4.0	-	-
Total sterols g/g dry wt.		85.8	3.2	14.3	17.8	4.0	1.9	9.7	5.9	24.1	76.9	52.7	18.9	19.2	12.1	62.9	17.5	6.6
coprostanol ng/L		3756	33.0	1954	1098	18.9	13.4	0	39.5									
coprostanol ng/g dry wt.										646	518	0	0	214	129	150	124	31.2
coprostanol g/g of carbon										34.4	5.8	0	0	5.8	4.8	2.7	5.0	2.7

* combined value includes small amounts of fucosterol

† combined value includes small amounts of isofucosterol

Two other important biomarker groups that occur in the NSN fraction are long-chain alkenones and diols. The long-chain alkenones are biomarkers for the presence of certain prymnesiophytes. These biomarkers are most abundant in the sediments from the centre of the Bay (Table 3). The presence of an unusual C_{28} alkyl-1,15-diol which elutes near 24-ethylcholesterol on the gas chromatograms could be evidence for the presence of eustigmatophytes. Eustigmatophytes of the genus *Nannochloropsis* have structurally analogous C_{30} and C_{32} diols (Volkman et al. 1992). The C_{28} diol occurs in sediments from Corio Bay, Hobsons Bay and the Central Zone (Table 3).

Table 3. Concentration of total sterols, long-chain alkenones, diols and tetrahymanol in sediments from Port Phillip Bay.

Zone	Site	Total Sterols (g/g dry wt)	Total Alkenones (ng/g dry wt)	Total Diol (ng/g dry wt)	Tetrahymanol (ng/g dry wt)
Corio Bay	37	32	-	-	-
	38	12	-	-	-
	39	29	323	339	17
	40	11	266	168	28
	41	14	89	145	4.1
Werribee	46	19	264	255	-
	17	4.7	78	-	2.4
	19	2.5	-	-	0.8
	34	5.9	83	68	2.9
	35	3.4	67	65	3.5
	36	11	241	180	-
	45	19	186	212	-
	5	0.6	10	3.2	2.1
	6	1.9	91	-	12
Hobsons Bay	22	1.1	10	-	1.4
	29	21	531	498	58
	33	2.9	77	85	6.9
	25	8.1	220	149	23
	26	12	162	205	26
	27	1.6	41	28	4.6
	28	2.2	51	34	1.8
Central Zone	1	2.8	116	-	10
	3	39	3795	-	191
	7	13	962	-	128
	8	7.1	683	-	68
	9	14	403	198	40
	10	5.7	140	-	23
	24	9.2	424	338	50
	30	9.3	339	258	43
Eastern Zone	2	8.5	446	-	28
	11	3.4	113	-	9.9
	13	1.9	-	-	1.7
	31	6.8	259	108	20
	32	3.6	159	65	12
	43	2.7	68	39	8.5
	44	6.4	24	-	3.4
Creeks	14	2.0	-	-	-
	15	23	340	-	37
	16	24	-	-	40
	18	59	-	-	-
	20	148	-	-	110
	21	40	-	-	-
	23	24	130	-	98

2.3.2 Total Extractable Fatty Acids

Fatty acids derived from the total extractable lipids (TEFA) following alkaline saponification (i.e. includes free fatty acids and fatty acids derived from triacylglycerols, glycolipids, phospholipids and other polar lipids) were the dominant components in all samples. TEFA compositional data are given in Tables 4a and b. Representative chromatograms are presented in Figure 4. A total of 58 fatty acids were identified (Table 4a,b). As many of the minor fatty acids accounted for less than 1% of the TEFA, they are not reported as individual components; rather they have been grouped as "other" for reporting purposes in Table 4a,b.

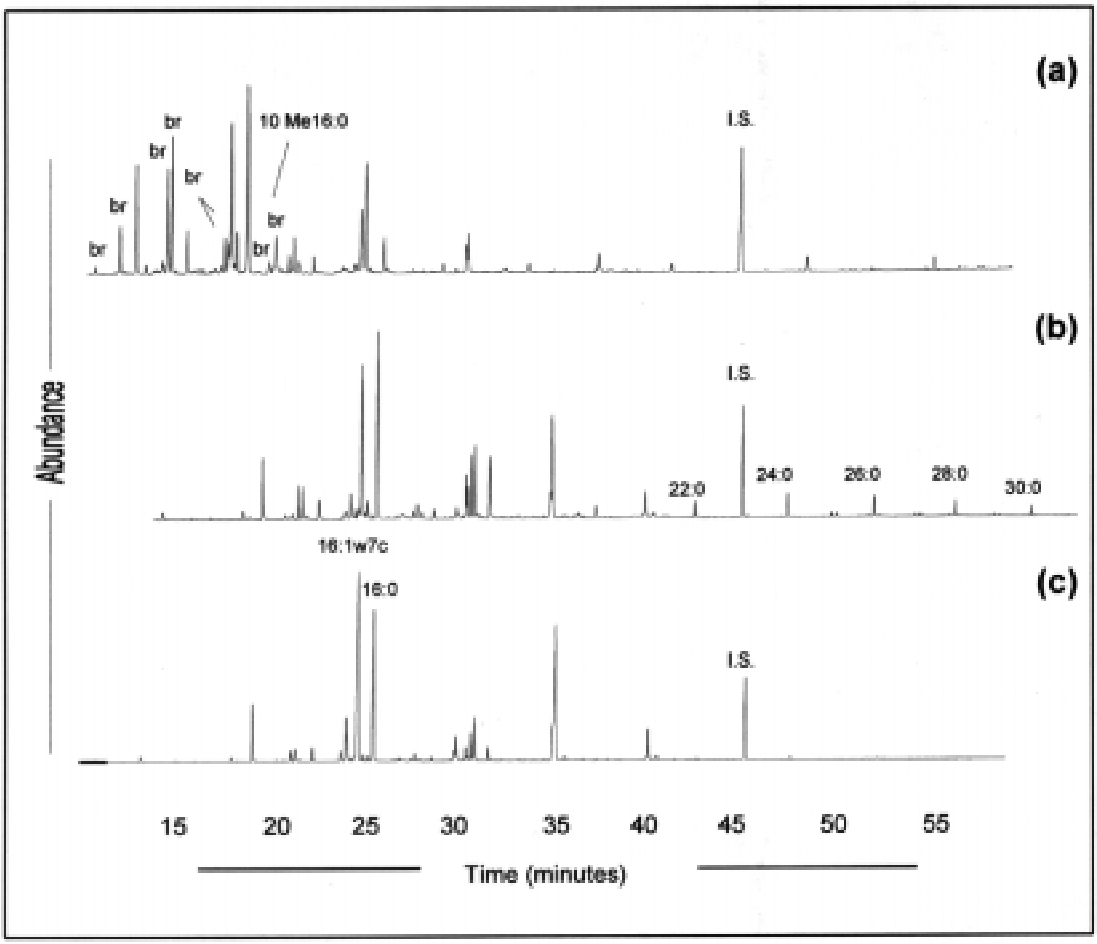

Figure 4. Partial chromatograms of the total extractable fatty acids from several sites. Trace (a) shows the branched chain fatty acids (br) which are biomarkers for bacteria. The biomarker for the sulphate reducing bacteria *Desulfobacter* (10Me16:0) is also shown. Trace (b) is from Kananook Creek and shows the long-chain fatty acids which can be used as biomarkers for terrestrial plant input. Trace (c) illustrates the high levels of 16:1ω7c compared to 16:0 which is typical of a fatty acid profile dominated by diatom input.

Fatty acids can be divided into four groups of compounds; saturated (no double bonds), monounsaturated (one double bond), polyunsaturated (two or more double bonds) and branched-chain fatty acids.

Saturated fatty acids are the most abundant group and comprise between 18.5% and 49% of the TEFA. The major fatty acids in this group were 16:0, representing up to 23% of the TEFA, and 14:0, comprising up to 6.7%. Long-chain fatty acids 24:0-32:0, which are terrestrial plant markers, are found in this group and accounted for up to 1.5% of the TEFA (Table 4). The Central Zone had consistently higher concentrations of long-chain fatty acids relative to other zones in the Bay. In the sediment from several of the creeks, long-chain fatty acids accounted for 3.5-4% of the TEFA. In sediments dominated by terrestrial input these fatty acids comprised up to 30% of the total fatty acids.

Monounsaturated fatty acids represent between 26.0% and 41.7% of the TEFA and are the second most abundant group of fatty acids. This group of acids contains 16:1ω7*c* (9.8-34.1%) which is commonly found in diatoms, 18:1ω7*c* which is abundant in bacteria and the unusual *trans* acid 18:1ω7*t* which is thought to be a marker for faecal pollution. The proportions of monounsaturated fatty acids vary greatly and there appears to be as much variation within zones as between zones.

Polyunsaturated fatty acids (PUFA) are found in algae and fauna. PUFA are readily degraded and provide an indication of the sources of fresh organic matter extracted from the sediments. PUFA comprise from 10.8% to 49.1% of the TEFA. The distribution of PUFA with respect to organic matter shows that fresh material is being deposited near Werribee and in Corio Bay and the eastern side of Hobsons Bay (Figure 5). The Central Zone shows much lower concentrations (0.05 - 0.9 mg/g TOM) which supports the suggestion that the organic matter in this zone is mostly refractory.

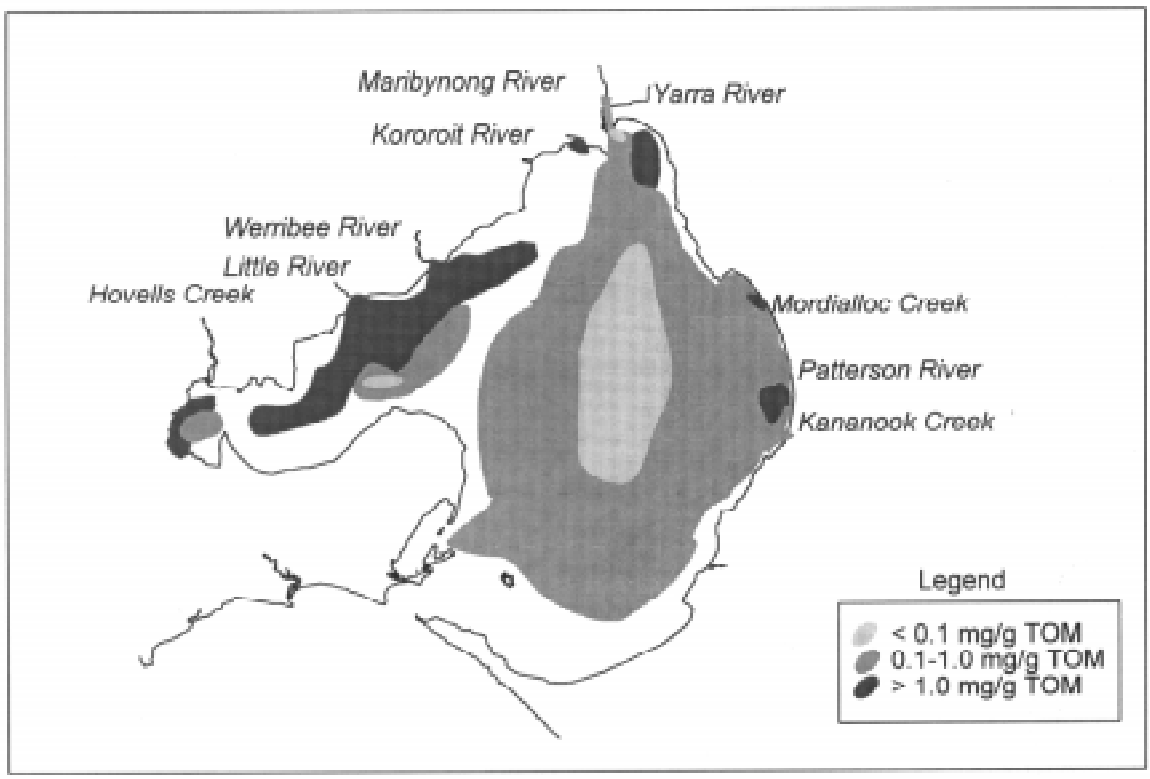

Figure 5. Distribution of total polyunsaturated fatty acids in Port Phillip bay sediments. The PUFA content gives an indication of the input of fresh organic material. The low levels in the Central Zone suggests that the majority of organic matter in this zone is possibly reworked or from secondary production.

Table 4a: Total extractable fatty acid content and composition of Port Phillip Bay sediments: Corio Bay and Werribee Zone.

	Percent Composition													
	Corio Bay					Werribee Zone								
Fatty Acid	37	38	39	40	41	46	17	19	34	35	36	45	5	6
12:0	0.7	0.3	0.3	0.3	0.2	0.2	1.5	0.1	0.2	0.3	0.5	—	0.2	0.2
13:0	0.2	0.1	0.3	0.3	0.3	0.2	0.2	0.1	0.1	0.6	0.3	—	0.2	0.1
i14:0	0.7	0.4	0.9	1.1	1.0	0.7	0.3	0.3	0.8	1.0	0.8	0.7	0.8	0.5
14:1ω7c	0.2	0.3	—	—	—	0.2	—	0.1	0.1	0.1	0.1	0.1	0.2	0.1
14:0	6.4	3.8	5.6	4.4	4.7	4.9	4.7	6.7	5.6	3.7	4.1	3.5	4.1	3.1
TMTD	0.1	—	0.2	0.3	0.2	0.1	—	0.1	0.1	0.2	0.2	0.4	—	—
i15:0	2.3	1.3	2.8	3.0	3.3	2.1	1.1	1.2	2.6	2.5	2.2	2.1	3.9	1.9
a15:0	2.1	1.4	4.6	5.8	4.8	3.0	1.2	1.6	3.2	4.4	3.3	2.6	4.2	2.9
15:1ω6c	0.4	0.2	0.4	0.8	0.3	0.5	—	0.3	0.4	0.5	1.6	0.3	0.1	0.2
15:0	1.8	1.2	2.7	4.3	2.6	3.4	0.8	1.9	1.5	3.5	4.8	1.9	1.3	1.8
Σ16PUFA	4.0	5.4	2.5	4.0	3.6	5.2	5.9	5.5	5.5	3.9	4.7	2.5	4.0	4.2
i16:0	0.8	0.4	1.1	1.1	1.2	0.6	0.3	0.3	0.6	0.9	0.8	0.8	0.8	0.5
16:1ω9c	0.8	—	1.1	0.9	1.2	—	0.4	0.3	—	0.9	0.7	0.8	1.4	0.8
16:1ω7c	11.7	20.5	11.5	16.8	12.3	15.0	24.4	26.4	18.1	19.4	15.4	9.8	19.0	22.7
16:1ω7t	0.3	0.1	0.2	0.4	0.3	0.1	—	0.1	0.2	0.4	0.2	0.3	0.3	0.2
16:1ω5c	1.5	0.8	1.5	1.5	1.5	1.0	0.6	0.6	1.4	1.4	1.2	1.0	1.3	0.9
16:1ω13t	0.6	0.8	0.1	0.1	0.2	0.3	0.5	0.5	0.4	0.2	0.2	0.1	0.3	0.4
16:0	18.0	17.1	13.7	15.4	13.5	13.4	17.3	19.2	14.3	15.2	14.6	16.5	15.8	15.5
i17:1	0.3	0.3	0.6	0.5	0.6	0.5	0.2	0.2	0.5	0.4	0.5	0.5	0.9	0.4
a17:1	—	0.2	—	—	—	0.1	—	0.2	0.1	0.1	0.7	0.1	—	0.1
10Me16:0	0.2	—	0.8	0.8	1.0	0.7	0.5	0.6	0.6	1.0	0.4	0.4	1.6	1.1
i17:0	0.6	0.4	0.8	0.9	0.9	1.7	0.3	0.6	0.5	0.4	0.6	1.0	0.7	0.4
17:1ω8c+a17:0	1.4	1.0	2.0	3.8	2.1	3.1	0.6	1.3	1.2	2.6	4.4	1.6	1.3	1.3
17:1ω6+cy17:0	0.8	0.4	0.9	1.2	0.5	0.4	0.3	0.3	0.6	0.9	1.0	0.6	0.7	0.6
17:0	0.7	0.6	1.1	1.0	1.1	0.8	0.3	0.4	0.6	0.9	0.9	1.3	0.7	0.7
Σ18PUFA	0.7	1.6	0.9	1.1	1.2	1.7	5.4	3.6	2.5	1.6	1.5	2.2	1.3	2.1
i18:0	—	0.2	0.3	—	—	0.1	0.1	—	0.1	0.1	0.1	0.4	0.7	0.1
18:2ω6	6.3	1.3	0.7	0.5	0.6	0.9	1.0	1.1	1.3	0.7	0.7	0.7	0.5	0.7
18:3ω3	1.6	0.5	0.5	0.6	0.4	0.3	0.2	0.3	0.4	0.4	0.4	0.6	—	0.2
18:1ω9c	5.5	2.1	3.1	2.6	3.4	2.4	2.1	1.8	2.6	3.4	2.5	2.6	9.8	2.6
18:1ω7c	4.3	4.2	7.2	7.1	7.9	5.9	4.3	3.6	6.8	7.8	5.8	6.7	3.3	5.8
18:1ω7t	0.4	0.3	0.2	0.2	0.3	0.1	—	0.1	0.2	0.3	0.2	0.2	—	0.1
18:0	3.4	2.6	2.7	1.6	2.9	2.2	1.1	0.8	1.6	1.7	1.7	3.0	1.4	1.2
cy19:0	0.1	—	0.2	0.2	0.6	0.2	0.1	—	0.1	0.3	0.2	0.3	0.2	0.2
19:0	0.1	—	0.3	0.2	0.2	0.2	—	—	0.1	0.1	0.1	0.2	—	0.1
20:4ω6	2.3	2.9	6.1	3.6	4.5	5.9	5.5	2.8	7.5	4.9	5.0	5.9	5.9	7.4
20:5ω3	11.5	17.7	12.3	8.5	9.5	11.2	15.5	12.4	11.3	7.0	11.1	10.6	7.1	12.5
Σ20PUFA	0.5	1.3	1.1	0.3	0.5	0.3	0.4	0.3	0.6	0.6	0.5	0.8	—	2.1
20:2ω6	0.4	0.3	0.3	0.1	0.3	0.3	0.1	0.1	0.2	0.2	0.3	0.6	0.3	0.1
20:1ω11/13	0.3	0.7	1.4	0.7	0.7	1.2	0.2	0.2	0.4	0.7	0.9	2.1	0.2	0.1
20:1ω7	0.2	0.3	0.3	0.2	0.4	0.4	—	0.1	0.2	0.2	0.2	0.6	1.0	0.1
20:0	0.4	0.3	0.6	0.5	0.8	0.6	0.1	0.1	0.4	0.2	0.3	0.6	—	—
22:5ω6	0.2	0.1	0.6	0.4	0.6	—	0.3	0.2	0.4	0.5	0.5	0.7	0.7	0.3
22:6ω3	1.9	2.6	3.9	1.4	2.6	3.6	3.0	1.9	2.1	1.4	1.7	7.4	1.5	1.7
22:4ω6	0.2	0.2	0.3	0.2	0.5	0.5	0.1	0.1	0.2	0.3	0.2	1.1	0.2	0.6
22:5ω3	1.0	0.7	0.4	0.3	0.4	0.4	0.3	0.2	0.3	0.4	0.3	0.8	0.2	0.2
22:0	0.3	1.7	0.2	0.2	0.9	0.6	—	—	0.2	0.8	0.2	0.6	—	—
Σ24:0-32:0	0.6	1.2	0.6	0.4	2.2	1.5	0.3	0.1	0.5	0.3	0.6	1.5	—	0.2
Others	1.3	0.4	0.2	0.4	1.5	1.1	0.2	1.3	1.0	0.9	1.4	0.8	1.9	0.9
tot µg/g dry wt	129	103	114	97	78	168	73	62	58	4	77	81	7	24
tot mg/g tom	4.8	7.2	4.9	3.8	1.6	4.0	14.6	8.1	18.8	0.5	4.0	3.4	3.2	3.8

Table 4b: Total extractable fatty acid content and composition of Port Phillip Bay sediments: Hobsons Bay and Central Zone

	Percent Composition														
	Hobsons Bay Zone							Central Zone							
Fatty Acid	22	29	33	25	26	27	28	1	3	7	8	9	10	24	30
12:0	—	0.4	0.7	—	0.4	—	0.4	0.3	0.4	0.5	0.5	0.2	0.3	—	—
13:0	—	0.2	0.2	—	—	—	—	0.2	0.3	0.4	0.3	0.1	0.3	—	—
i14:0	—	0.9	1.5	1.3	1.3	—	0.4	0.7	1.4	2.1	1.9	0.5	1.4	1.8	1.1
14:1ω7c	—	0.2	—	—	—	—	—	0.1	—	—	—	—	—	—	—
14:0	3.9	4.7	5.5	4.9	4.5	2.3	5.2	4.1	5.1	5.3	5.6	6.7	5.5	5.3	4.4
TMTD	—	0.8	0.7	0.5	—	—	—	0.1	0.4	0.4	0.3	0.1	0.4	—	—
i15:0	0.9	2.6	5.0	4.6	4.4	1.0	0.9	2.8	4.9	5.7	6.1	1.6	4.8	7.0	4.0
a15:0	0.9	3.4	7.6	4.5	6.1	1.5	1.1	4.0	4.8	7.9	7.7	1.8	5.8	8.7	4.7
15:1ω6c	0.1	0.1	π	—	—	—	—	0.1	0.2	0.2	0.1	—	0.3	—	—
15:0	1.5	1.5	1.9	1.6	2.5	1.2	1.2	1.5	1.7	2.6	2.8	0.9	2.5	2.8	1.9
Σ16PUFA	3.6	3.0	1.8	1.6	0.8	5.4	5.1	2.5	1.5	1.0	0.6	3.8	1.1	—	—
i16:0	—	0.8	2.3	1.4	1.5	—	—	0.7	1.4	2.0	2.2	0.5	1.6	2.5	1.5
16:1ω9c	—	0.9	1.2	2.2	1.2	—	0.3	1.3	2.2	2.2	1.9	0.6	1.7	2.4	1.7
16:1ω7c	34.1	12.2	11.5	12.0	10.6	21.9	28.6	18.3	12.9	10.9	9.8	12.5	11.1	10.2	10.5
16:1ω7t	—	0.3	0.5	0.3	0.6	—	0.2	0.2	0.3	0.6	0.4	—	0.4	0.6	—
16:1ω5c	0.4	1.4	2.3	2.3	1.8	0.6	0.5	1.2	2.3	2.4	2.2	0.9	2.2	2.6	1.8
16:1ω13t	0.4	0.2	0.1	0.1	—	0.2	0.3	0.2	0.2	—	—	0.4	0.1	—	—
16:0	23.6	15.8	15.9	13.8	16.8	12.7	20.1	14.7	14.5	14.6	15.9	11.3	14.9	17.1	16.2
i17:1	0.2	0.5	0.7	0.9	0.8	—	—	0.6	1.0	1.0	0.7	0.1	0.8	1.1	0.8
a17:1	0.3	0.5	1.8	1.5	1.2	—	—	2.6	2.2	3.0	3.0	0.8	1.9	2.6	1.7
10Me16:0	—	0.6	1.1	0.9	1.5	—	—	0.5	0.9	1.0	1.1	0.4	0.9	1.3	1.0
i17:0	—	—	—	0.1	—	—	—	—	0.1	0.2	—	—	0.1	—	—
17:1ω8c+a17:0	0.9	1.1	2.6	1.7	2.2	0.9	0.6	1.6	1.8	2.5	1.4	0.8	1.8	2.9	2.1
17:1ω6+cy17:0	0.0	0.4	0.8	1.0	0.9	—	—	0.7	1.0	1.0	1.1	0.4	1.1	1.4	0.9
17:0	0.3	0.8	1.0	0.9	1.4	0.4	0.3	0.8	0.8	1.2	1.3	0.6	1.0	1.3	1.2
Σ18PUFA	2.2	1.8	0.7	—	0.6	3.1	2.5	1.1	0.5	0.8	0.1	1.4	1.5	—	1.0
i18:0	—	0.3	—	0.1	—	0.2	—	0.1	0.1	0.1	—	0.1	—	—	0.1
18:2ω6	0.9	0.7	0.7	0.7	1.0	1.1	1.0	0.7	0.7	0.5	0.3	0.8	0.8	0.6	0.6
18:3ω3	0.3	0.6	0.9	0.5	0.6	0.6	0.3	0.4	0.2	0.4	0.7	0.1	0.2	0.8	0.6
18:1ω9c	2.0	2.4	4.1	4.0	4.1	3.3	2.3	3.5	3.9	4.6	4.9	4.7	4.9	5.2	7.2
18:1ω7c	3.8	5.3	6.1	8.1	7.3	6.0	3.7	9.5	8.6	7.9	7.6	6.7	7.5	8.1	7.7
18:1ω7t	—	0.3	0.1	0.2	0.4	—	—	0.1	0.2	0.3	0.3	—	0.3	—	0.8
18:0	1.1	2.4	3.1	2.6	5.5	1.2	1.2	1.8	2.2	2.5	3.1	2.5	2.4	2.8	6.9
cy19:0	—	—	0.5	0.6	0.2	—	—	0.3	0.6	0.7	0.7	0.3	0.6	0.6	0.7
19:0	—	—	0.2	0.2	0.3	—	—	0.1	0.2	0.3	0.3	0.2	0.3	—	0.4
20:4ω6	3.3	3.2	2.2	4.6	4.4	5.4	4.5	4.7	5.6	2.2	2.2	2.2	3.3	2.7	2.4
20:5ω3	11.3	13.4	5.7	6.9	6.2	24.0	15.5	11.4	5.1	2.0	2.9	25.4	5.0	2.1	3.7
Σ20PUFA	0.4	1.0	0.4	0.4	—	—	—	0.4	0.2	—	—	0.4	—	—	0.3
20:2ω6	0.3	0.4	0.2	0.3	—	—	—	0.1	0.4	0.1	0.1	0.2	0.3	—	0.3
20:1ω11/13	0.4	0.7	0.5	0.8	—	—	—	0.4	0.2	0.3	0.6	0.1	0.2	—	1.6
20:1ω7	0.2	0.4	0.4	0.2	—	—	—	0.1	0.2	0.1	0.2	0.6	0.1	—	0.5
20:0	0.0	0.6	1.1	0.8	0.6	—	—	0.2	0.5	0.9	0.8	0.3	0.6	0.8	1.1
22:5ω6	0.2	0.5	0.3	0.7	0.6	0.4	0.2	0.3	0.6	0.3	0.3	0.2	0.4	0.3	0.4
22:6ω3	1.6	7.7	2.4	4.7	3.7	4.8	2.8	2.3	3.2	1.4	1.7	6.1	4.0	1.4	2.2
22:4ω6	0.1	0.4	0.3	0.6	1.0	0.2	0.1	0.2	0.3	0.2	0.2	0.1	0.4	0.2	0.2
22:5ω3	0.3	1.0	0.5	0.7	0.4	0.8	0.3	0.2	0.3	0.2	0.7	0.5	0.3	0.3	0.4
22:0	0.1	0.6	0.4	0.6	0.6	0.8	0.1	0.2	0.4	0.7	0.7	0.1	0.4	0.6	1.1
Σ24:0-32:0	0.3	2.5	0.7	2.1	1.7	—	0.3	0.5	1.4	2.3	3.3	0.6	2.1	2.2	3.1
Others	—	0.6	1.8	1.1	0.4	—	—	1.3	2.3	2.6	2.8	1.3	2.1	—	0.9
tot µg/g dry wt	24	65	14	25	30	10	29	23	183	54	33	136	28	30	53
tot mg/g tom	10.8	1.5	0.4	1.0	0.9	1.9	5.4	2.3	2.2	0.8	1.0	2.1	1.5	0.6	1.0

Table 4c: Total extractable fatty acid content and composition of Port Phillip Bay sediments: Creeks and Eastern Zone.

	Percent Composition													
	Creeks							Eastern Zone						
Fatty Acid	14	15	16	18	20	21	23	2	11	13	31	32	43	44
12:0	—	0.3	0.7	0.1	0.3	0.5	0.4	0.2	—	—	0.3	—	0.4	0.1
13:0	—	0.2	0.2	0.1	0.2	—	0.3	0.2	—	—	0.2	—	0.3	0.2
i14:0	0.4	0.8	0.7	0.4	0.7	0.8	0.8	0.7	0.6	0.2	1.4	0.5	0.5	0.2
14:1ω7c	0.1	0.4	0.3	0.1	0.3	0.3	0.2	0.1	—	—	—	—	—	0.3
14:0	3.5	5.8	4.5	2.2	4.2	6.6	4.1	4.3	3.4	3.4	4.6	4.1	3.3	3.4
TMTD	0.2	0.3	0.4	0.1	0.2	0.4	0.2	0.3	0.2	—	0.5	—	0.1	—
i15:0	2.0	2.5	2.4	1.3	2.4	3.2	2.1	2.4	2.1	0.7	5.0	1.9	1.8	1.3
a15:0	2.0	2.9	2.4	1.6	2.4	2.9	2.8	3.3	3.1	1.0	5.3	2.7	2.6	1.3
15:1ω6c	0.3	0.5	0.4	0.2	0.5	0.3	0.5	0.2	0.2	0.3	0.2	—	0.2	0.2
15:0	2.3	2.3	1.7	1.0	1.8	1.7	2.4	1.6	1.9	2.1	2.0	1.6	1.8	1.8
Σ16PUFA	6.2	4.3	3.1	5.1	3.6	2.0	3.4	4.2	3.7	4.5	0.6	5.3	4.7	3.3
i16:0	0.4	0.4	0.6	0.3	0.4	0.7	0.6	0.6	0.6	0.1	1.7	0.6	0.6	0.1
16:1ω9c	0.6	0.6	0.8	—	—	1.1	—	1.1	0.7	0.3	2.2	0.7	0.8	0.1
16:1ω7c	19.3	15.8	12.4	27.5	14.9	13.5	18.4	15.4	16.0	28.7	11.1	22.4	20.6	26.8
16:1ω7t	0.2	0.4	0.4	—	0.2	0.3	0.2	0.3	0.2	0.4	0.4	0.3	0.3	—
16:1ω5c	0.6	1.7	1.5	0.6	1.0	1.7	1.1	1.1	1.0	0.4	2.4	1.0	1.0	0.6
16:1ω13t	0.8	0.4	0.3	0.8	0.7	0.3	0.4	0.2	13.2	0.3	0.1	0.5	0.4	0.3
16:0	16.5	17.4	17.5	15.5	17.1	20.2	15.2	14.5	13.2	19.2	14.1	15.6	15.0	18.1
i17:1	0.3	0.4	0.4	0.3	0.5	0.6	0.5	0.5	0.4	0.1	0.9	0.4	0.4	0.2
10Me16:0	2.1	0.6	0.6	0.4	0.1	—	0.4	1.5	0.9	0.6	1.8	0.6	0.7	0.1
i17:0	1.0	0.7	1.3	0.5	0.7	0.7	0.8	0.6	0.3	0.5	1.2	0.4	0.4	0.5
17:1ω8c+a17:0	2.1	1.4	0.7	1.0	1.6	1.2	2.1	1.3	1.2	1.5	2.1	1.2	1.4	1.1
17:1ω6+cy17:0	0.5	0.8	0.7	0.5	1.1	0.3	0.9	0.6	0.5	0.4	1.2	0.6	0.6	0.3
17:0	0.8	0.6	0.2	0.6	0.9	0.8	1.0	0.8	0.7	0.6	1.3	0.7	0.8	0.6
Σ18PUFA	2.4	3.2	0.9	1.6	3.8	0.4	1.7	1.4	1.3	2.3	—	2.3	2.0	3.3
i18:0	—	0.2	—	0.2	0.3	—	0.2	0.2	0.1	0.1	0.2	—	0.2	0.2
18:2ω6	1.1	1.4	3.4	1.2	1.4	2.2	1.0	0.6	0.9	1.4	0.6	0.7	0.7	1.1
18:3ω3	0.3	0.4	1.4	0.4	2.4	0.5	0.5	0.6	0.4	0.2	0.5	0.3	0.3	0.4
18:1ω9c	2.5	2.7	5.0	2.7	2.5	6.5	2.4	2.8	2.9	1.9	4.4	2.7	3.1	2.3
18:1ω7c	5.0	4.5	5.6	5.4	7.0	5.9	6.7	6.6	5.4	3.9	7.8	5.6	6.3	3.1
18:1ω7t	0.2	0.2	0.3	0.1	0.2	0.4	0.2	0.2	—	—	0.2	0.2	0.2	0.1
18:0	1.6	1.6	4.5	1.4	1.8	3.4	2.1	1.8	1.7	1.1	2.6	1.6	1.5	1.4
cy19:0	0.1	0.2	—	0.1	0.1	—	0.1	0.2	0.2	0.1	0.7	0.1	0.2	0.6
19:0	0.1	—	0.2	0.1	0.1	—	0.1	0.2	0.2	0.1	0.3	—	0.1	0.1
20:4ω6	5.0	2.4	2.5	4.8	4.6	1.7	6.9	6.8	4.5	4.5	4.6	4.2	5.4	6.7
20:5ω3	12.8	11.5	9.0	15.5	10.3	6.0	10.8	11.9	13.1	14.0	5.1	14.4	14.9	13.5
Σ20PUFA	0.4	0.3	—	0.6	0.2	0.2	0.7	0.6	—	0.3	0.4	0.3	0.4	0.4
20:2ω6	0.1	0.1	0.3	0.1	0.3	4.2	0.2	0.3	0.1	0.1	0.5	0.2	0.3	0.4
20:1ω11/13	0.1	0.3	0.6	0.1	0.9	0.4	0.5	0.3	0.2	0.3	0.8	0.7	0.9	0.1
20:1ω7	0.1	0.1	—	0.2	0.3	0.3	0.2	0.3	0.2	0.1	0.4	0.3	0.2	0.2
20:0	0.4	0.6	1.1	0.2	0.4	0.2	0.5	0.2	0.3	—	1.0	0.3	0.4	0.2
22:5ω6	0.2	0.2	0.2	0.1	0.2	0.3	0.2	0.6	0.3	0.2	0.6	0.4	0.4	0.3
22:6ω3	3.6	2.2	2.4	1.9	1.7	4.4	2.6	4.9	2.1	1.7	4.1	2.3	2.9	2.4
22:4ω6	0.3	0.2	0.3	0.2	0.4	0.2	0.3	0.7	0.2	0.2	0.3	0.2	0.2	0.2
22:5ω3	0.3	0.6	0.3	1.0	1.4	0.6	0.9	0.7	0.3	0.8	0.4	0.3	0.4	0.4
22:0	0.3	0.6	1.4	0.2	0.4	0.3	0.3	0.2	0.2	0.4	0.4	0.5	0.1	0.1
Σ24:0-32:0	0.7	5.1	5.8	0.7	1.0	1.1	1.0	0.5	1.3	0.1	1.1	1.1	0.1	0.1
Others	0.6	0.6	1.2	1.3	2.3	1.1	0.9	1.5	0.3	1.0	2.0	0.1	0.1	1.7
tot µg/g dry wt	22	119	214	260	599	167	112	48	31	27	38	32	28	93
tot mg/g tom	6.4	3.3	3.4	14.3	8.6	1.9	3.8	2.5	2.8	2.9	0.9	2.2	2.7	17.8

Table 4d: Total extractable fatty acid content and composition for Port Phillip Bay influent creek water column and sediments.

	Percent Composition																
	Water Column								Sediment								
Fatty Acid	47	49	50	51	52	53	54	55	47	49	50	51	52	53	54	55	56
i14:0	0.1	-	0.2	0.4	-	0.1	0.2	0.7	0.1	1.1	0.6	0.2	1.0	0.6	0.3	0.7	0.2
14:1ω7c	-	-	-	-	-	-	-	-	-	0.2	0.1	0.1	0.2	0.1	0.1	0.1	0.1
14:0	1.4	1.6	0.8	3.4	0.3	1.1	2.4	0.4	0.7	4.0	4.8	2.4	4.0	2.6	10.0	5.8	3.7
TMTD	-	0.2	0.2	-	-	0.2	0.1	-	0.1	0.2	0.1	0.4	0.2	0.2	0.2	0.4	0.0
i15:0	1.1	1.4	1.9	2.3	0.4	1.3	1.0	0.4	1.0	4.6	1.9	0.7	3.7	2.6	1.1	1.7	0.5
a15:0	0.6	0.7	1.5	1.9	0.2	0.7	1.0	0.5	0.6	3.7	1.5	0.3	3.0	1.7	0.1	2.6	0.4
15:1ω6c	-	-	-	0.5	-	-	0.1	-	0.1	0.5	-	0.1	0.3	0.1	0.2	0.2	0.5
15:0	1.9	0.7	0.7	2.9	0.4	0.8	0.6	0.7	1.0	1.7	1.9	0.6	1.2	1.1	0.8	1.9	3.0
Σ16PUFA	1.5	0.9	0.7	-	0.1	0.3	3.2	1.2	1.1	2.8	4.5	1.0	2.6	2.5	10.4	2.5	4.8
i16:0	14.3	0.6	2.0	0.7	0.5	1.0	0.4	0.5	0.6	0.9	1.9	0.6	1.4	1.1	0.8	0.9	-
16:1ω7c+16:1ω9c	4.2	15.0	12.0	14.0	12.6	12.9	18.5	17.0	9.8	14.4	12.9	3.7	10.6	10.8	20.3	23.9	32.6
16:1ω7t	0.1	-	-	0.8	-	-	1.2	-	0.1	0.1	0.5		0.5				
16:1ω5c	0.3	0.5	0.6	0.7	0.7	0.5	0.7	0.4	0.3	1.6	2.4	0.4	3.6	1.3	1.2	0.6	-
16:1ω13t	1.8	0.2	1.9	0.8	0.9	0.5	0.4	0.3	0.4	0.2	0.5	0.1	0.2	0.3	0.3	0.3	-
16:0	12.7	20.0	18.8	17.6	21.6	27.7	21.4	25.7	18.9	18.9	20.9	11.0	19.9	17.8	15.3	20.0	24.0
10Me16:0	-	-	-	0.6	-	-	-	-	0.7	0.5	0.3	0.4	1.4	1.3	0.1	0.6	0.2
i17:0	1.0	0.3	0.4	0.7	0.2	0.4	0.1	0.5	1.2	0.1	0.4	1.1	0.9	0.9	0.2	0.4	0.1
17:1ω8c+a17:0	0.3	1.0	0.4	3.5	1.0	1.1	0.3	1.3	0.7	1.1	0.7	0.5	0.5	0.6	0.4	1.1	1.5
17:1ω6+cy17:0	0.2	0.4	0.3	4.7	0.4	0.4	0.1	0.6	0.6	1.3	0.7	0.4	1.3	0.6	0.4	0.8	0.4
17:0	0.8	0.7	0.7	1.8	0.5	0.7	0.4	1.2	2.0	1.2	0.7	1.4	0.9	1.1	0.3	1.1	0.6
Σ18PUFA	3.5	2.1	4.0	1.3	13.7	7.2	2.4	3.2	0.7	0.8	1.3	0.3	0.7	1.5	0.2	0.5	1.4
18:2ω6	4.6	4.3	4.3	2.6	2.5	4.7	8.7	3.2	2.4	3.7	4.6	4.0	4.3	1.2	3.8	3.0	1.0
18:3ω3	-	-	-	6.8	-	-	-	-	-	-	-	-	-	-	-	-	-
18:1ω9c	38.5	9.4	29.7	12.5	7.2	8.2	12.5	7.5	7.8	5.8	12.1	8.5	6.1	6.1	4.5	5.4	1.8
18:1ω7c	1.7	19.0	5.6	6.1	15.0	16.2	5.2	15.5	9.7	9.1	4.6	6.1	8.2	7.2	2.4	7.2	1.7
18:1ω7t	-	-	-	0.9	-	-	-	-	0.5	0.3	0.2	0.8	0.4	0.1	0.1	0.1	0.0
18:0	1.3	5.5	3.2	4.7	4.7	5.4	3.9	6.6	6.7	2.7	4.2	13.6	4.0	4.2	1.4	1.9	0.8
cy19:0	0.1	0.2	0.1	0.1	-	0.1	0.1	0.3	0.2	0.8	0.3	0.3	1.1	0.6	0.1	0.4	-
19:0	0.2	0.1	-	0.2	-	-	0.1	0.1	0.6	0.1	0.1	0.6	0.2	0.2	0.0	0.1	-
20:4ω6	1.1	1.0	0.3	0.6	-	0.3	0.9	1.9	3.3	3.7	1.4	2.6	3.0	3.7	5.0	4.4	1.9
20:5ω3	2.6	4.9	2.0	1.7	10.8	5.6	7.1	7.6	5.6	5.8	7.9	2.9	4.0	14.9	15.2	5.8	15.3
Σ20PUFA	0.2	0.2	0.1	-	0.2	0.1	1.0	-	1.2	0.7	0.3	1.2	0.3	1.0	0.6	0.7	0.4
20:2ω6	-	-	-	0.2	-	-	0.1	-	2.5	0.1	0.1	2.9	0.3	0.8	0.0	-	0.2
20:1ω7	-	-	-	0.3	-	0.1	-	-	0.9	0.1	0.1	0.2	0.1	0.2	0.0	0.1	0.1
20:0	0.3	0.7	0.4	0.4	0.4	0.1	0.3	0.7	1.9	0.7	0.3	3.5	1.6	0.5	0.3	0.4	0.1
22:5ω6	1.0	0.2	0.2	0.6	-	-	0.5	-	0.5	0.1	0.3	0.4	0.2	0.4	0.6	0.2	0.1
22:6ω3	0.5	6.2	0.5	0.6	4.7	1.2	2.5	1.4	0.7	0.7	0.9	0.4	0.9	3.3	1.2	0.4	1.4
22:5ω3	-	0.1	-	0.1	-	-	0.1	-	1.6	0.4	0.1	0.6	0.2	2.0	0.1	0.4	0.5
22:0	-	0.5	0.3	0.3	0.3	0.2	0.3	0.2	2.4	0.6	0.2	5.6	1.6	0.4	0.3	0.3	0.1
Σ24:0-32:0	-	0.3	0.1	-	-	-	-	-	4.9	2.0	0.4	5.4	2.0	0.9	0.7	0.2	0.4
Others	3.0	1.3	6.2	1.9	0.6	0.9	1.7	0.9	5.6	3.1	1.4	11.8	3.0	3.4	0.7	2.5	0.3
tot mg/g dry wt	535	19	55	146	13.9	19.8	80.2	28.2	9.4	21.6	458	3.5	35.5	43.5	545	163	172
tot mg/g tom									0.5	0.2	3.8	0.2	1.0	1.6	9.9	6.6	12.5

Branched chain fatty acids are markers for bacteria and represent between 2.2% and 26% of the total fatty acids present in Port Phillip Bay sediments. The branched fatty acids include *i*14:0, *i* and *a*15:0, *i*16:0, *i* and *a*17:1, 10Me16:0, *i*17:0, *i*18:0, *i* and *a*19:0 and cy19:0. The relative abundance of branched acids in the sediments from Corio Bay, Werribee and the western side of Hobsons Bay is consistent with these regions being depositional zones which are rich in organic material. By comparison there was a relatively low abundance of branched fatty acids (between 6.2 and 9.9% of the TEFA) in the creek sediments (Table 4b). Branched fatty acids include minor quantities of 10Me16:0 and *i*17:1ω7c, which are markers for sulfate reducing bacteria. They comprise between 0 and 3% of the TEFA and are generally most abundant in the Central Zone and creek sediments.

2.3.3 Polar Lipid Fatty Acids

The polar lipid fatty acid (PLFA) composition may be used to provide information on microbial biomass and community structure. PLFA compositional data is given in Table 5. Minor fatty acids are grouped together as "other" for reporting purposes. A representative chromatogram is presented in Figure 6. The sedimentary PLFA profiles were dominated by short-chain (C_{14}-C_{22}) components which is indicative of a bacterial source. The concentration of PLFA in the Port Phillip Bay sediments was between 2 and 54 times lower than values measured for the TEFA (Table 5). Considerable variation in PLFA concentrations between and within zones was also observed. The concentration of PLFA in Port Phillip Bay sediments followed a slightly different trend to that observed for the TEFA (i.e. creeks > Corio Bay > Werribee Zone > Central Zone > Hobsons Bay and Eastern Zone).

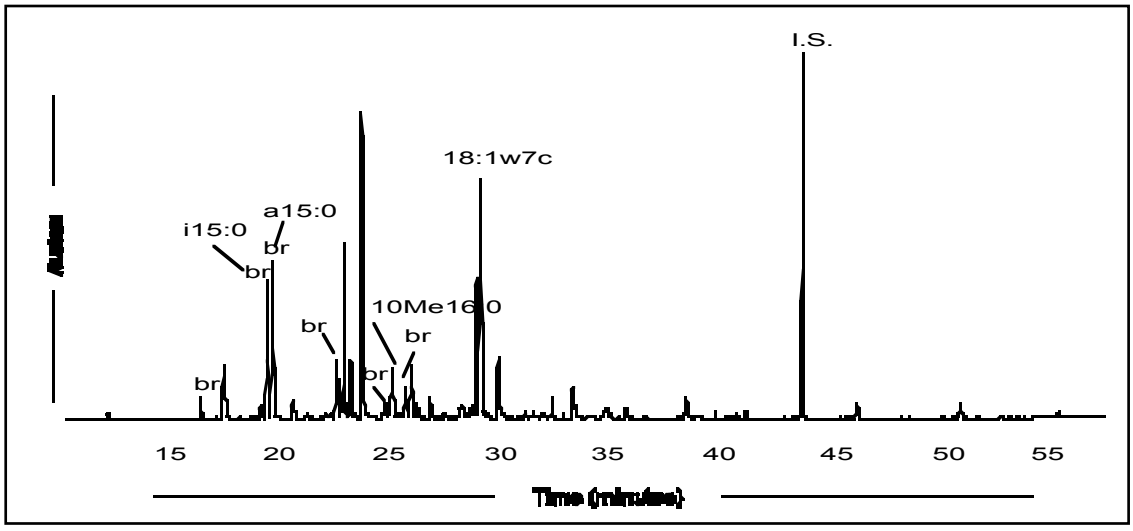

Figure 6. Chromatogram of PLFA fraction for sediment from the Central Zone showing high concentrations of iso and anteiso 15:0 and 18:1 7c which are biomarkers associated with bacterial input and also the high concentrations of 10Me16:0 the biomarker indicative of the sulfate reducing bacteria *Desulfobacter*. **Note** that at this high content of branched fatty acids many of the saturated and mono-unsaturated straight chain fatty acids are also likely to originate from bacteria.

Table 5a. Polar Lipid Fatty Acid content of Port Phillip Bay sediments: Corio Bay and Werribee Zone.

	Percentage Composition													
	Corio Bay						Werribee Zone							
Fatty Acid	37	38	39	40	41	46	17	19	34	35	36	45	05	06
i14:0	0.8	0.4	0.8	1.3	1.2	0.8	0.3	0.5	0.8	1.1	0.9	0.5	0.7	0.7
14:0	6.3	3.4	4.4	4.5	3.8	4.8	3.4	6.0	5.9	4.6	5.2	2.3	3.6	3.5
i15:1	0.3	0.2	0.2		0.2	0.2	0.1	0.1	0.3			0.2	0.3	
tmtd			0.3	0.3	0.4	0.2	0.1		0.2			0.6		
i15:0	2.8	1.8	3.2	4.5	4.7	2.7	1.5	2.2	3.2	4.0	3.2	2.0	5.1	3.2
a15:0	2.8	1.7	5.5	8.1	6.8	3.9	1.3	2.2	3.4	6.1	4.7	2.5	4.4	4.1
15:16	0.3	0.1	0.2	0.2	0.1	0.3		0.1	0.4			0.1		
15:0	1.8	1.1	1.5	2.1	1.6		0.7	1.9	1.1	2.0	2.5	0.9	1.0	1.2
16PUFA		0.2	0.3	0.6	0.3	1.2	1.1	1.6	0.9	1.2	1.0	0.4	1.8	1.1
i16:0	1.1	0.7	1.1	1.9	1.8	1.1	0.6	0.6	1.0	1.5	1.3	0.8	1.2	1.1
16:19c	1.0	0.6	1.2	1.4	1.6	1.3	0.8	1.0	1.4	1.5	1.4	0.9	1.6	1.2
16:17c	9.4	9.8	8.5	12.5	10.2	11.2	13.6	15.0	13.3	14.3	13.0	6.6	16.3	15.2
16:17t	0.4	0.3	0.2	0.4	0.2	0.3			0.3			0.1	0.3	0.4
16:15c	1.4	0.6	1.6	2.2	2.2	1.4	0.8	0.9	1.7	1.6	1.8	1.1	1.6	1.4
16:113t	0.8	0.6	0.2	0.3	0.3	0.4	0.8	1.3			0.4	0.2	0.5	0.6
16:0	20.4	18.0	13.8	17.5	16.0	16.1	21.7	22.4	19.4	21.7	19.7	18.0	20.5	22.6
i17:1			0.2	0.3	0.3	0.7	0.4	0.4	0.5			0.5	1.1	0.5
10Me16:0	0.3	0.3	0.7	1.0	1.3	0.7	0.6	0.4	0.6	1.0	0.7	0.6	1.4	0.9
i17:0	0.7	0.7	1.0	1.1	1.2	1.5	0.5	0.7	0.7	0.9	0.8	1.1	1.1	0.6
17:18c+a17:0	1.7	1.4	2.1	3.3	2.5	2.7	0.9	1.5	1.7	2.4	2.3	1.3	1.6	1.6
17:16+cy17:0	1.1	0.6	1.0	1.2	1.2	0.9	0.4	0.4	1.0	1.0	1.1	0.5	0.9	0.8
17:0	1.1	1.1	1.2	1.3	1.3	1.2	0.7	0.8	0.9	1.2	1.1	1.6	0.8	1.1
18PUFA	1.1	0.3	0.3	0.4	0.3	0.9	1.4	3.4	1.5	1.2	1.2	0.5	1.7	1.6
i18:0		0.4	0.3			0.2	0.2		0.2			0.4	0.1	0.2
18:26	3.5	1.5	0.3	0.5	0.5	0.8	0.9	1.0	1.1		0.8	0.5	0.4	0.5
18:33	1.0	0.4	0.3	0.5	0.3	0.3	0.2	0.3	0.4		0.3	0.4	0.5	0.5
18:19c	5.0	3.0	3.4	4.6	4.6	4.4	3.6	3.5	4.4	5.1	4.5	3.2	4.1	4.7
18:17c	8.3	7.5	8.8	11.3	11.2	10.9	8.1	6.3	11.1	11.7	11.3	8.5	11.2	8.9
18:17t	0.2	0.2	0.1	0.2	0.2	0.2						0.2		0.2
18:0	3.7	3.8	3.2	2.8	3.8	3.3	3.1	2.7	2.9	4.4	3.9	3.8	1.7	3.3
cy19:0	0.3	0.2	0.5	0.6	0.9	0.4	0.1		0.3	0.5	0.5	0.3	0.4	0.4
19:0	0.3	0.2	0.3	0.2	0.2	0.2						0.2		0.2
20:46	2.0	3.2	7.7	3.2	4.5	5.1	4.9	3.7	5.2	3.5	4.6	6.4	4.2	4.5
20:53	9.2	17.0	11.3	2.9	4.0	6.3	13.1	8.5	6.8	3.1	5.5	6.8	3.9	4.3
20PUFA		0.9	1.4		0.3	0.2	0.4					1.6	0.3	
20:26	0.4	0.5	0.3		0.2	0.3	0.2	0.2	0.3			0.6	0.2	0.2
20:111/13c	0.9	1.4	1.9	0.6	1.2	1.6	0.2	0.6	0.4		1.4	2.5	0.4	1.0
20:17	0.5	0.6	0.3	0.3	0.4	0.5	0.4	0.1	0.4		0.4	0.8	0.2	0.4
20:0	0.5	0.4	0.4	0.4	0.4	0.3	0.3	0.3	0.3		0.3	0.3	0.3	0.3
22:56	0.3	0.4	0.9	0.6	0.8	0.8	0.8	0.6	0.6	0.7	0.8	1.1	0.8	0.8
22:63	2.5	5.0	5.1	2.2	3.2	6.3	7.9	5.4	3.3	2.0	2.6	12.7	1.5	3.6
22:46	0.3	0.7	0.4	0.4	0.7	0.8	0.4	0.5	0.4		0.5	2.0	0.2	0.7
22:56	1.4	2.1	0.3	0.3	0.5	0.5	0.6	0.2	0.3		0.5	1.1	0.2	0.4
22:0	1.0	0.8	0.3	0.4	0.4	0.4	0.8	0.4	0.4			0.3	0.5	0.6
24:0-32:0	3.2	3.7	0.6	0.6	0.4	0.6	1.2	1.0	0.6	0.6		0.2	0.7	0.8
Others	-	2.0	2.2	1.0	1.5	1.3	0.7	1.3	0.5	1.2		2.8	0.7	0.4
tot g/g dry wt.	18.9	6.4	25.4	13.1	18.6	19.0	8.5	6.4	8.3	2.6	11.4	28.7	2.9	3.4
tot mg/g TOM	0.7	0.4	1.1	0.5	0.4	0.5	1.7	0.8	2.7	0.3	0.6	1.2	1.3	0.5

Table 5b. Polar Lipid Fatty Acid content of Port Phillip Bay sediments: Hobsons Bay and Central Zone.

	Percentage Composition														
	Hobsons Bay Zone			Central Zone											
Fatty acid	22	29	33	25	26	27	28	01	03	07	08	09	10	24	30
i14:0	0.5	0.7	1.4	1.0	0.9	0.5	0.5	0.9	1.4	1.5	1.5	0.4	1.1	0.9	1.4
14:17	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
14:0	4.2	3.0	4.5	3.6	2.4	3.2	4.9	3.4	3.9	3.6	2.7	2.7	3.1	2.9	3.9
TMTD	0.0	1.4	0.8	0.5	0.6	0.0	0.3	0.2	0.4	0.5	0.2	0.0	0.4	0.0	0.4
i15:0	2.3	2.8	6.1	4.3	4.1	2.1	1.9	4.0	5.9	6.3	6.8	2.1	5.0	6.2	6.3
a15:0	1.9	3.3	8.8	4.3	5.6	2.7	1.8	4.8	5.6	8.5	8.3	2.1	6.1	7.9	7.5
15:16	0.0	0.0	0.0	0.2	0.4	0.2	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
15:00	1.4	0.9	1.4	1.0	1.2	1.3	1.1	1.3	1.2	1.5	1.7	0.6	1.5	1.7	1.5
16PUFA	1.7	0.2	0.0	0.0	0.4	0.6	0.8	1.0	0.8	0.0	0.0	0.2	0.0	0.0	0.4
i16:0	0.6	1.1	3.8	1.5	1.6	0.7	0.6	1.3	1.9	2.7	2.8	0.8	2.3	2.9	2.4
16:19c	1.2	1.0	1.2	2.0	1.0	0.8	0.9	1.2	2.0	2.1	2.0	0.9	2.1	2.1	2.4
16:17c	18.4	8.0	10.1	8.3	6.6	12.4	16.9	10.9	9.3	8.3	7.4	6.1	7.6	7.9	0.0
16:17t	0.0	0.3	0.5	0.0	0.4	0.0	0.0	0.2	0.1	0.5	0.3	0.0	0.4	0.0	10.0
16:15c	0.7	1.4	2.1	2.4	1.6	1.0	0.8	1.4	2.7	3.0	2.8	1.1	2.7	2.8	0.0
16:113t	1.1	0.2	0.2	0.0	0.0	0.5	0.8	0.2	0.3	0.0	0.0	0.2	0.0	0.0	3.0
16:0	24.1	18.2	16.4	14.8	16.6	18.8	23.4	17.5	14.4	15.3	18.3	13.5	16.7	18.7	16.2
i17:1	0.3	0.5	0.5	0.9	0.8	0.3	0.0	0.8	1.2	1.0	1.0	0.2	0.8	1.0	0.4
10Me16:0	0.5	0.5	2.4	2.6	1.1	0.4	0.3	2.4	2.6	3.2	3.3	0.8	2.1	3.8	3.0
i17:0	0.4	1.1	1.4	1.2	1.9	0.4	0.5	0.8	1.3	1.4	1.6	0.6	1.4	1.6	1.4
17:18c+a17:0	1.3	1.4	3.1	2.0	2.6	1.4	1.1	2.0	2.2	2.9	3.0	0.9	2.5	3.8	2.6
17:16+cy17:0	0.4	0.5	0.9	1.1	1.0	0.6	0.4	0.9	1.3	1.6	1.5	0.5	1.5	1.8	1.5
17:0	0.7	1.2	0.8	1.0	1.6	1.1	0.9	1.1	1.0	1.2	1.5	0.9	1.3	1.3	1.1
18PUFA	0.9	0.3	0.9	0.0	0.0	1.0	0.9	0.9	0.8	1.6	0.0	0.2	0.4	0.0	0.0
i18:0	0.0	0.6	0.2	0.0	0.4	0.2	0.2	0.2	0.2	0.0	0.0	0.2	0.0	0.0	0.0
18:26	0.7	0.5	0.6	0.3	0.8	0.6	0.6	0.6	0.3	0.5	0.3	0.8	0.5	0.0	0.0
18:33	0.0	0.5	0.7	0.5	0.2	0.0	0.0	0.2	0.2	0.6	0.3	0.0	0.0	0.0	0.0
18:19c	3.5	3.1	4.7	5.0	5.1	4.7	3.1	4.2	4.9	6.6	6.8	8.0	7.2	8.6	6.2
18:17c	7.1	8.2	9.4	10.0	9.4	8.3	7.7	10.5	10.9	12.4	11.3	8.8	11.5	12.8	11.1
18:17t	0.0	0.2	0.0	0.0	0.3	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
18:0	3.0	2.8	4.0	3.2	5.8	4.2	4.2	3.3	2.9	2.6	4.4	5.0	3.5	3.0	2.8
cy19:0	0.0	0.3	0.8	1.0	0.5	0.3	0.0	0.5	1.1	1.3	1.4	0.5	1.1	1.6	1.1
19:0	0.0	0.0	0.0	0.2	0.3	0.0	0.0	0.2	0.2	0.0	0.1	0.2	0.3	0.0	0.0
20:46	3.9	3.5	2.3	4.9	4.8	4.7	3.8	4.5	5.5	1.8	1.9	2.7	3.6	0.4	2.7
20:53	9.3	8.3	3.2	3.8	5.8	12.8	10.0	8.6	2.5	0.5	1.9	22.9	2.8	1.8	2.4
20PUFA	0.3	1.5	0.0	0.2	0.0	0.0	0.0	0.3	0.4	0.0	0.0	0.2	0.4	0.0	0.0
20:26	0.2	0.7	0.0	0.4	0.2	0.3	0.3	0.2	0.4	0.1	0.1	0.4	0.4	0.0	0.0
20:19/11c	0.4	1.0	1.3	1.4	0.6	1.3	0.8	0.7	1.2	1.1	0.6	1.3	0.6	1.5	0.9
20:17	0.4	0.8	0.0	0.4	0.2	0.5	0.4	0.2	0.3	0.2	0.1	0.7	0.3	0.0	0.4
20:0	0.2	0.4	0.5	0.4	0.4	0.4	0.3	0.5	0.4	0.6	1.3	0.7	0.5	0.7	0.5
22:56	0.6	0.9	0.3	0.9	1.2	0.8	0.7	0.6	0.8	0.4	0.2	0.5	0.8	0.5	0.5
22:63	5.5	12.4	3.1	6.0	6.8	8.1	6.7	4.3	4.1	1.2	1.3	9.9	3.5	1.1	3.7
22:46	0.2	1.1	0.4	1.1	2.4	0.6	0.3	0.4	0.4	0.3	0.2	0.2	0.9	0.3	0.3
22:56	0.4	1.6	0.7	0.7	0.7	1.0	0.5	0.6	0.3	0.4	0.2	0.8	0.4	0.3	0.4
22:0	0.4	0.3	0.3	0.3	0.3	0.5	0.5	0.5	0.4	0.6	0.6	0.4	0.4	0.0	0.2
24:0-32:0	1.3	0.8	0.3	0.6	0.4	0.6	0.9	0.5	0.6	2.1	0.3	0.5	0.4	0.0	0.4
Others	0.0	2.6	0.0	6.0	1.1	0.0	0.0	1.2	1.6	0.0	0.0	0.4	1.6	0.0	0.9
g/g dry wt	3.8	16.4	2.0	8.8	8.3	4.0	5.4	5.7	58.7	7.9	4.0	18.1	3.7	6.9	15.2
g/g TOM	1.61	0.38	0.06	0.37	0.26	0.73	1.01	0.56	0.69	0.12	0.17	0.28	0.21	0.13	0.29

Table 5c. PolarLipid Fatty Acid composition of Port Phillip Bay sediments: Creeks and Eastern Zone.

	Percentage Composition													
	Creeks							Eastern Zone						
Fatty acid	14	15	16	18	20	21	23	2	11	13	31	32	43	44
i14:0	0.3	0.9	0.6	0.4	0.5	1.3	0.8	0.7	0.4	0.1	1.2	0.8	0.8	0.2
14:17	0.0	0.7	0.0	0.1	0.4	0.4	0.2	0.0	0.0	0.0	0.0	0.0	0.0	0.0
14:0	3.0	6.0	3.3	1.8	3.6	4.2	3.3	2.8	2.0	2.5	3.7	4.7	3.9	3.1
TMTD	0.1	0.3	0.4	0.1	0.1	0.5	0.2	0.4	0.0	0.0	0.5	0.0	0.0	0.0
i15:0	2.2	2.9	2.5	1.8	1.8	5.2	2.6	2.8	2.5	1.0	5.1	3.2	3.0	1.0
a15:0	2.1	3.2	2.4	1.8	1.7	4.8	3.1	3.2	3.5	1.2	5.5	4.1	3.8	1.3
15:16	0.1	0.3	0.3	0.1	0.3	0.3	0.2	0.1	0.0	0.0	0.0	0.0	0.0	0.8
15:0	2.0	1.7	1.2	1.0	1.3	1.5	1.6	1.0	0.8	1.3	1.4	1.2	1.1	1.6
16PUFA	1.0	0.7	0.3	1.5	0.6	0.6	1.1	0.6	0.5	1.2	0.0	1.6	1.1	0.6
i16:0	0.7	0.9	1.1	0.6	0.7	1.5	0.9	1.0	1.2	0.4	1.9	1.1	1.1	0.3
16:19c	0.8	0.0	1.3	0.0	0.7	1.4	0.6	1.0	1.2	0.6	2.3	1.4	1.3	0.7
16:17c	15.0	11.7	11.3	11.8	7.7	13.6	11.5	9.3	12.4	15.2	7.7	16.2	14.7	10.2
16:17t	0.1	0.2	0.4	0.3	0.4	0.4	0.3	0.1	0.0	0.1	0.0	0.0	0.0	0.0
16:15c	0.6	1.6	1.4	0.5	0.9	2.1	1.0	1.2	1.3	0.4	2.6	1.5	1.5	0.4
16:113t	1.8	1.0	0.5	0.8	0.9	0.3	0.5	0.6	0.5	0.8	0.0	0.7	0.6	0.5
16:0	21.8	19.0	18.8	18.2	15.8	16.6	16.5	16.6	20.3	22.9	14.7	22.1	20.4	20.1
i17:1	0.4	0.5	0.4	0.5	0.5	0.9	0.6	0.6	0.5	0.0	0.9	0.0	0.3	0.2
10Me16:0	1.1	0.5	0.8	0.3	0.4	1.5	0.9	1.0	0.9	0.3	2.3	0.7	0.7	0.0
i17:0	0.8	1.0	0.8	0.9	1.1	1.1	0.7	0.9	0.8	0.6	1.3	0.6	0.6	0.5
17:18c+a17:0	1.9	1.5	1.6	1.2	2.0	2.0	2.0	1.6	1.9	1.2	2.2	1.5	1.6	1.0
17:16+cy17:0	0.5	1.0	0.9	0.4	0.9	1.0	1.0	0.7	0.8	0.4	1.3	0.9	0.9	0.3
17:0	1.0	1.0	1.0	1.1	1.3	1.1	0.1	1.2	1.3	1.1	1.6	1.0	1.1	0.9
18PUFA	0.3	0.1	0.8	0.2	0.3	0.5	0.2	0.2	0.0	0.0	0.0	1.2	0.0	0.0
i18:0	0.1	0.6	0.3	0.2	0.6	0.2	0.3	0.4	0.0	0.3	0.0	0.0	0.0	0.2
18:26	1.0	1.0	2.4	1.4	0.9	1.2	0.6	0.5	0.7	0.9	0.5	0.4	0.4	0.6
18:33	0.3	0.3	0.7	0.3	1.0	0.4	0.3	0.2	0.6	0.0	0.0	0.0	0.0	0.2
18:19c	3.5	3.9	6.3	5.9	3.9	4.8	3.6	3.6	6.1	3.0	6.2	4.2	4.4	3.1
18:17c	6.6	7.6	12.3	8.0	9.5	10.5	9.6	7.7	10.3	6.6	10.6	9.6	9.6	4.6
18:17t	0.2	0.1	0.2	0.1	0.2	0.2	0.2	0.2	0.0	0.0	0.0	0.0	0.0	0.0
18:0	2.7	2.6	4.1	3.5	3.1	3.3	3.8	3.4	4.0	3.6	2.8	3.3	3.7	3.7
cy19:0	0.3	0.4	0.6	0.1	0.1	0.4	0.2	0.3	0.0	0.0	1.1	0.0	0.4	0.0
19:0	0.1	0.0	0.2	0.1	0.1	0.2	0.2	0.2	0.0	0.0	0.5	0.0	0.3	0.4
20:46	6.2	4.7	3.0	6.0	0.0	1.8	3.7	6.6	5.0	6.2	4.9	3.8	4.5	8.4
20:53	8.2	8.2	4.6	13.4	17.5	2.2	10.4	8.3	8.1	9.3	4.5	5.7	7.4	19.2
20PUFA	0.5	0.7	0.6	0.5	1.4	0.2	0.4	1.0	0.0	0.7	0.0	0.0	0.0	2.3
20:26	0.1	0.4	0.3	0.3	0.4	0.8	0.3	0.6	0.0	0.1	0.6	0.0	0.3	0.5
20:19/11c	0.2	1.4	1.5	0.8	2.1	0.0	1.6	1.8	1.1	1.2	2.3	0.8	0.5	0.0
20:17	0.2	0.3	0.3	0.6	0.7	0.3	0.5	0.5	0.4	0.3	0.4	0.0	0.3	0.2
20:0	0.3	0.2	0.4	0.3	0.3	0.4	0.4	0.4	0.5	0.0	1.4	0.0	0.7	0.3
22:56	0.4	0.0	0.5	0.0	0.5	0.5	0.0	1.3	0.8	0.6	0.9	0.6	0.8	0.7
22:63	8.1	4.2	3.8	5.3	4.1	4.6	5.1	8.6	6.2	4.0	5.1	4.3	5.3	4.6
22:46	0.5	0.9	0.4	0.6	1.1	0.2	0.8	1.9	0.8	1.1	0.5	0.3	0.3	0.4
22:56	0.3	1.5	0.7	2.4	3.5	0.5	1.4	1.4	0.4	2.9	0.4	0.6	0.3	0.4
22:0	0.5	0.3	0.6	0.4	0.3	0.6	0.7	0.8	0.7	0.3	0.5	0.4	0.4	0.3
24:0-32:0	0.9	0.8	1.9	1.6	0.8	1.7	2.7	0.7	0.8	1.0	0.4	0.6	0.5	1.0
Others	0.7	2.1	1.6	2.5	2.6	1.6	2.4	2.0	0.4	5.6	0.0	0.0	0.6	4.1
g/g dry wt	4.5	45.5	4.0	40.1	86.0	32.8	22.5	10.9	2.5	4.2	9.7	4.4	5.8	7.7
g/g TOM	1.29	1.26	0.36	1.94	1.24	0.38	0.73	0.58	0.23	0.46	0.22	0.31	0.56	1.48

Branched chain fatty acids comprised between 4.0% and 26.7% of the PLFA analysed in Port Phillip Bay sediments thereby indicating that bacteria are major contributors to the PLFA fraction. The PLFA concentrations showed no significant trends in most of the zones with the exception of the Central Zone and the eastern side of Hobsons Bay where the proportions of branched fatty acids were relatively high at 26.7% and 25.3% respectively (Figure 7, Table 5).

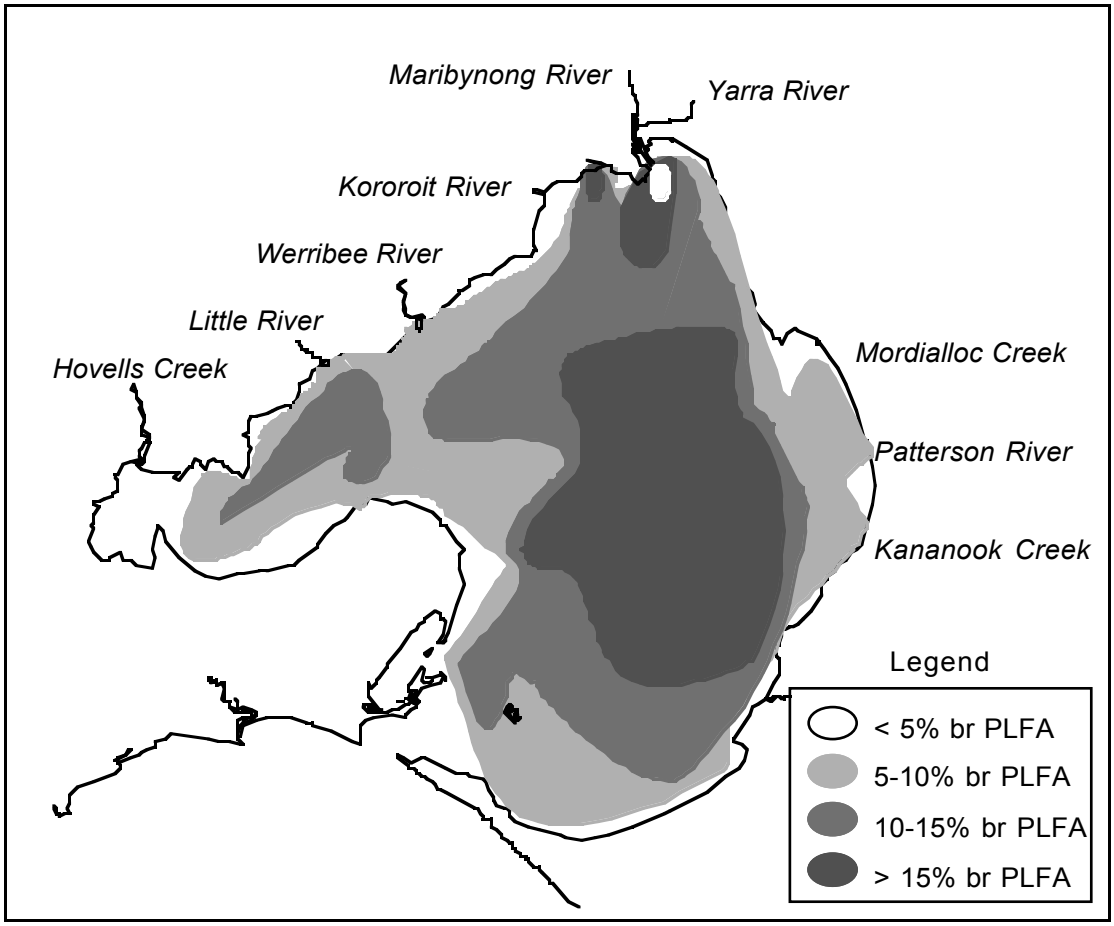

Figure 7. Bacterial contribution to PLFA in Port Phillip Bay sediments. The higher abundance in the Central Zone, Hobsons Bay and Corio Arm indicates the increased contribution of viable bacterial biomass in these areas of the Bay.

Biomarkers for sulfate reducing bacteria including 10Me16:0 and *i*17:17c were present in slightly greater quantities than in the TEFA fraction (0- 4% of PLFA). The distribution of these markers in Bay sediments was similar to that of the TEFA fraction (Figure 8).

Conversion of PLFA concentration data into number of cells per gram of sediment can be calculated for the samples using the following approximations: average bacteria the size of *E. coli* contain 27 mg of PLFA per gram (dry weight basis) and 1 g of bacteria is equivalent to 5.9 x 10^{12} cells (dry weight) (White et al., 1979). Using these conversion factors, approximate microbial cell concentrations (i.e. viable cells) of between 4.4 and 32 x 10^{8} cells g^{-1} dry weight were calculated for the Bay sediments (Table 5).

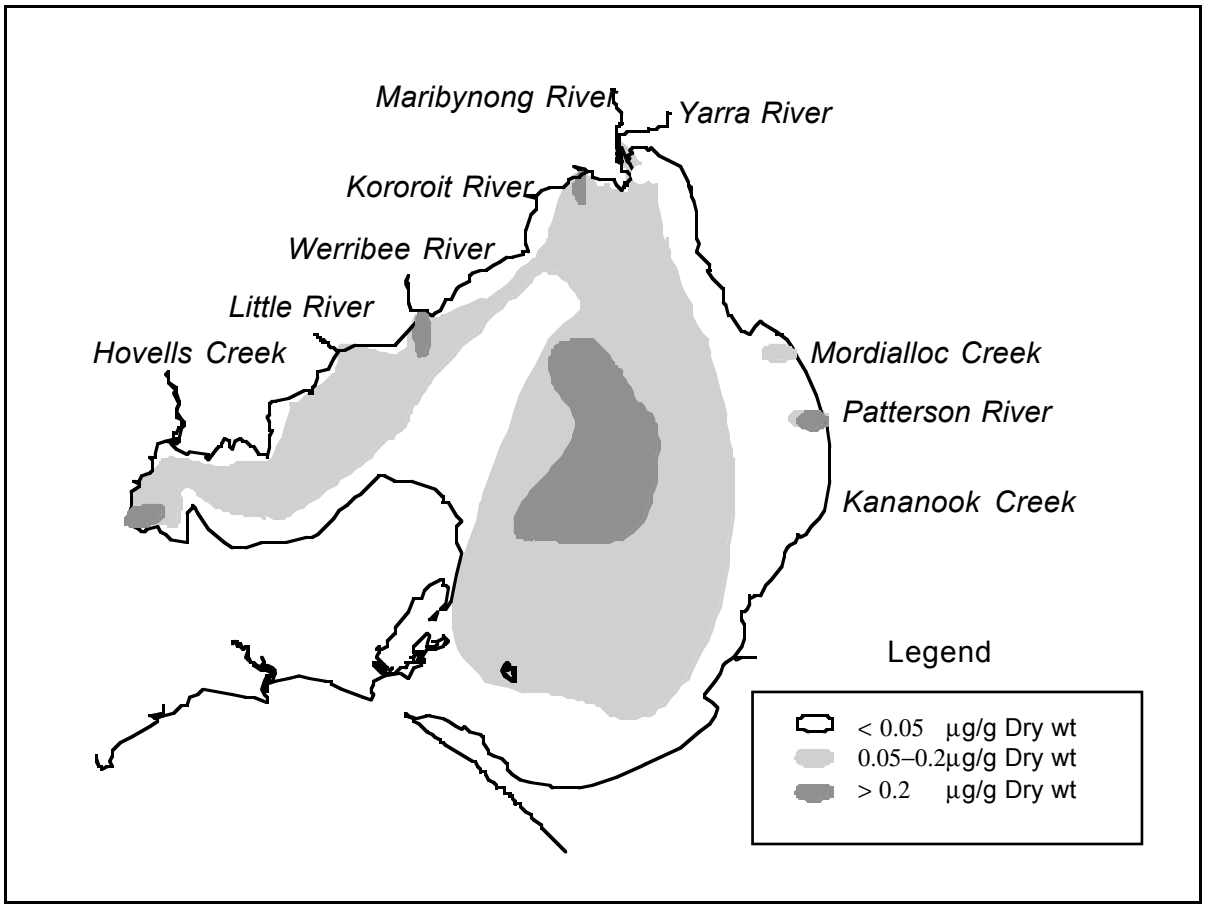

Figure 8. Distribution of biomarkers for viable sulfate reducing bacteria in the PLFA fraction from Port Phillip Bay sediments. There is a twofold increase in the concentration of these specific biomarkers in the sediments from the Central Zone.

3.0 DISCUSSION

3.1 Sources

This study of the organic biomarkers contained in the sediments of Port Phillip Bay and its influent streams identified differences within and among four principal sources of organic carbon in Port Phillip Bay sediments. These were sewage, carbon from primary production (algal), carbon from secondary production (bacterial) and the input of organic matter from terrestrial vegetation.

The discussion below concerning organic biomarkers is based on the absolute concentration (i.e. weight of compound per dry weight of sediment) and also on the concentration relative to total organic matter (TOM). The method of comparison with TOM contributes to the assessment in terms of the relative input from different carbon sources. In this study the organic matter is determined from loss on ignition at 450^0C with no prior acidification. This value will be greater than the actual organic carbon content.

3.2 Sewage Biomarkers

The principal findings regarding sewage biomarkers from this study are that;

1. Human sewage appears to be entering Port Phillip Bay via the influent streams
2. The Corio Bay and Werribee Zone and Central Zone are the sites most influenced by sewage
3. Several sites in Hobsons Bay and two sites in the Eastern Zone are also affected by sewage

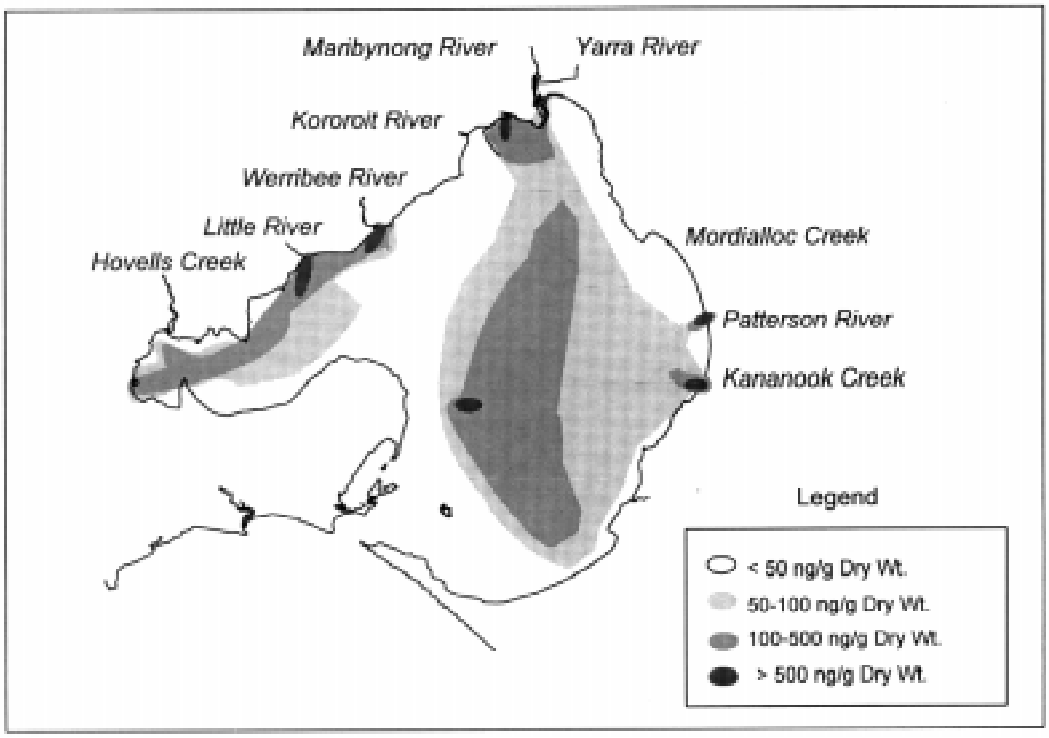

Figure 9. Distribution of the faecal sterol, coprostanol, in Port Phillip Bay sediments. The abundance shows an accumulation of sewage derived material in the Central Zone and Corio Bay. Inputs appear to be the Yarra River, WTP and the creeks.

The faecal indicator coprostanol was detected in most sediment samples and typically comprised between 0.5 and 2% of the total sterols (Table 2). Concentrations in the influent creek sediments ranged from 0 - 2580 ng g^{-1} (dry weight) and comprised between 1.7 and 8.7% of the total sterols. Coprostanol concentrations in Port Phillip Bay sediments ranged from 4 - 549 ng g^{-1} (dry weight) with normalised concentrations ranging from 1.4 - 22 μg g^{-1} organic material. Sediments directly adjacent to the WTP main drain had concentrations of 645 ng g^{-1} dry weight and 34 μg g^{-1} organic material. The dry weight concentration of coprostanol was more than 100 ng g^{-1} at 3 of the 5 sites in the Corio Bay Zone and at sites #46 and #36 in the Werribee Zone, sites #29 and #26 in the Hobsons Bay Zone, 3 of the 8 sites in the Central Zone and site #2 in the Eastern Zone (Table 2). Sediments collected from Elwood Canal, Kananook Creek, Werribee River and Hovells Creek also showed elevated concentrations of coprostanol (Table 6). The general distribution of faecal contamination in Port Phillip Bay, based on coprostanol measurements, was as follows; Corio Bay and Werribee > Hobsons Bay ≥ sites #11, #44 > the rest of the Central and Eastern Zone sites (Figure 9).

The concentration of coprostanol in the influent stream water column samples (taken in April 1994) was comparatively high. These influent creeks may be an important source of faecal contamination in Port Phillip Bay. Water samples collected at the WTC outfall had a coprostanol concentration of 3760 ng L^{-1} which is 100 times less than the concentration of Sydney's primary treated effluent (300 μg L^{-1}). Water samples collected from the Mordialloc Creek showed high concentrations (2000 ng L^{-1}) when compared to more pristine environments. Coprostanol was also detected in lesser amounts in water samples collected from Elwood Canal, Kananook Creek, Hovells Creek and the Werribee River. Coprostanol was not detected in water from uncontaminated sites.

Table 6. Coprostanol concentrations in water column and sediment from some of the creeks and rivers flowing into Port Phillip Bay.

Sample sites	sediment (June 93) *ng/g dry wt*	water (April 94) *ng/litre*	sediment (April 94) *ng/g dry wt*
Mouth of Hovells Creek	–	40	124
Little River	1754	–	–
Werribee Treatment Plant	–	3756	645
Mouth of Werribee River	2584	13	128
Werribee River, Werribee	–	0	150
Kororoit River	585	–	–
Yarra River	1495	–	–
Elwood Canal	–	33	517
Mordialloc Creek #1	53	1953	0
Mordialloc Creek #2	–	1098	0
Patterson River	917	–	31
Kananook Creek	2077	18	214

The finding that faecal matter is entering Port Phillip Bay via the influent streams is consistent with the operation of 13 smaller sewage treatment facilities around Port Phillip Bay. Some of these facilities experience wet (and dry) weather overflows into adjacent waterways. The results of this study strongly imply that the faecal matter measured at these sites (using the faecal signature coprostanol) is of human origin. Domestic animals such as dogs do not contain coprostanol in their faeces. A major study has been undertaken in conjunction with Australian Water Technologies-Science and Environment to determine if any other animals that are ubiquitous in urban environments contain coprostanol in their faeces (Leeming et al., 1994). The results so far indicate that cats are the only common domestic animal capable of biohydrogenating cholesterol to coprostanol in relatively similar proportions; absolute amounts would of course be much lower. This is not to say that domestic and urban animals do not contribute to faecal contamination, but the major source of coprostanol in influent creek sediments is believed to be from human sewage.

In environments considered to be grossly polluted, such as areas adjacent to sewage outfalls (i.e. within 2 km of Sydney's deep ocean outfall at Malabar), coprostanol concentrations range from about 500 to 3000 ng g^{-1} dry weight and from 19 to 68 µg g^{-1} of TOM (Nichols et al., 1992 and Leeming and Nichols, unpublished data). Derwent estuary sediments adjacent to sewage outfalls showed coprostanol concentrations of 600 - 1800 ng g^{-1} dry weight and 3.6 - 11.3 µg g^{-1} TOM respectively (Leeming, unpublished data). Sediments from the Port Phillip Bay influent streams contained similar or higher coprostanol concentrations in comparison to both of those environments (Table 6 and Figures 9 & 10).

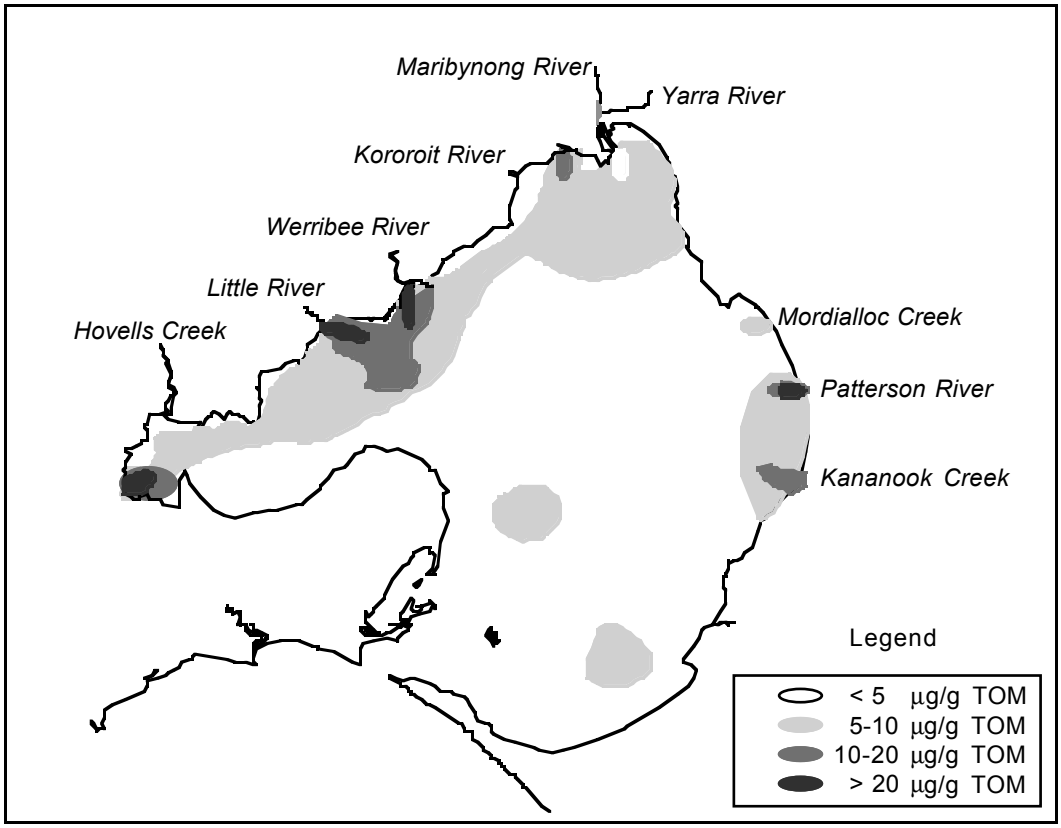

Figure 10. Contribution of the faecal sterol, coprostanol, relative to total organic matter in Port Phillip Bay sediments.

Surface input into Port Phillip Bay is dominated by the flow from the Yarra River at approximately 890,000 megalitres per year (Hunter, 1992). The annual flow from WTP is approximately 160,000 megalitres per year (Murray, 1994) with the remaining rivers, creeks and drains constituting 497,000 megalitres between them. The output of sewage derived material from the small creeks and drains is not likely to affect the Bay as a whole, but the impact on their local environment could be significant. From the limited water-column data we have to date, the loading of faecal biomarkers being discharged annually from Mordialloc Creek is about one tenth that of WTP.

The quantitative significance of this result to Port Phillip Bay is difficult to establish without knowing the loading of sewage from each stream (further water column sampling and flow gauging data are required). Furthermore, the spatial distribution of sampling sites in Port Phillip Bay was not designed to reveal trends from point sources (the creeks) to sites in the Bay that showed elevated coprostanol concentrations (i.e. site #44). A more comprehensive examination of the input of faecal matter from influent streams is recommended.

The concentration of coprostanol in Port Phillip Bay sediments varies in relation to the proximity of point sources of sewage and to water circulation in the Bay with its consequent effect on sediment type and deposition rates. For instance, given the known source and very high load of sewage effluent discharged off Werribee, the concentration of coprostanol is quite variable and not elevated in sediment from the Werribee Zone (ranging from 5 - 260 ng g^{-1} (dry weight)). However, as a fraction of the organic matter being deposited in this region, faecal matter is proportionately elevated (Figure 10) compared to other regions within the Bay. There are at least two reasons for the low absolute amounts of coprostanol in the Werribee Zone. The first is that the sewage treatment at Werribee is efficient. Concentrations of coprostanol in Werribee effluent are two orders of magnitude less than Sydney's primary treated effluent. The extended residence times in holding lagoons at the WTP means the time available for removal or degradation of organic material is quite long compared with most sewage treatment facilities and the resultant flux of coprostanol to Port Phillip Bay from this particular source may be comparatively low. Secondly, the Werribee Zone appears to be an active, non-depositional environment characterised by sandy sediments. Consequently such an environment would be very efficient at dispersing and degrading those organic constituents which are discharged.

Corio Bay is also affected by sewage and has elevated concentrations of organic matter comprising algal, bacterial and sewage biomarkers in higher proportion [to carbon] than any other zone in Port Phillip Bay. Sewage from the city of Geelong is discharged to Bass Strait via the Black Rock outfall and not into Corio Bay. It is therefore possible that the source of sewage contamination in this zone is from the WTP (unless there are local and/or illegal inputs of faecal matter). The sediment type (silty sand) and the elevated organic input suggest that Corio Bay is a depositional area and may be a sink for faecal matter and nutrients. Additional information concerning water circulation and currents in the area may help confirm such an assessment.

Several other sites around Port Phillip Bay showed evidence of faecal pollution. Sites #22 and #29 close to the mouth of the Yarra River contained relatively high coprostanol concentrations relative to TOM; this observation may indicate an input of faecal pollution *via* the river. Sites #26 and #28 to the south of these sites and further away from the river mouth contained progressively lower concentrations of coprostanol, displaying a logical trend of decreasing concentration of biomarker with increasing distance from the source.

For the rest of the Bay some care must be taken interpreting results for coprostanol concentrations because of background inputs of this sterol, especially at sites remote from possible sources. Where a known point source can be identified and a trend of decreasing concentrations away from that source can be established, coprostanol is an accurate and reliable biomarker. But coprostanol does occur in anoxic sediments not contaminated by faecal matter and can also occur in trace amounts in aerobic sediments (Nishimura, 1982) Data gathered for sediments from many pristine environments show that coprostanol concentrations in aerobic sediments are typically < 50 ng g^{-1}, < 2 μg g^{-1} TOM and < 10% of the corresponding 5α-cholestanol concentration (Leeming et al., unpublished).

To gain further insight on other sources of coprostanol it is useful to examine signature lipid distributions for anaerobic microbial communities. For example the fatty acids 10Me16:0 and *i*17:1ω7*c* are derived from sulfate reducing bacteria which are present in anoxic sediments and the concentration of these components can therefore be used to indicate the degree of anoxia in sediments.

Sediment from most sites in the central region had slightly elevated proportions of sulfate reducing bacteria (Tables 4 and 5), as did sites #25 and #33 in Hobsons Bay and sites #2 and #31 in the Eastern Zone indicating anoxia in the surface sediments. Only three sites appear to have both elevated proportions of sulfate reducing bacteria and elevated coprostanol concentrations. These were sites #3 and #10 in the Central Zone and site #26 in Hobsons Bay. This finding may explain why there were above-background concentrations of coprostanol at several remote [from sewage inputs] Central Zone sites.

The only other sites which are affected by sewage contamination are sites #44 and #11 which are proximate to Patterson River and Kananook Creek (creek sites #15 and #16). Neither of these sites showed very high absolute concentrations of coprostanol, but they did contain moderately high proportions of coprostanol relative to TOM. Furthermore, both sites were in areas characterised by sandy sediments with little or no indication of anoxia. The general water circulation is clockwise in Port Phillip Bay and sites #11 and #44 are both down current from Patterson River and Kananook Creek. Since coprostanol is strongly bound to particulate matter and the sediments in both the above mentioned creeks showed extremely high concentrations of coprostanol, it is possible that this result is an indication of faecal contamination from the influent streams.

Effluent and sludge from sewage treatment plants (primary STPs) typically contain $3x10^5$ ng L^{-1} and 10^6 ng g^{-1} of coprostanol (unpublished data). The coprostanol concentrations found in the creek sediments correspond to dilution factors of between 1/380 to 1/20000 relative to sewage sludge. The calculated lower dilution factors are in the range where overseas studies have observed significant and reproducible toxic effects in laboratory experiments with sewage sludge. The precise cause of these effects was not determined but probably reflected the presence of toxic inorganic and organic chemicals. It is beyond the scope of this study to comment further on any possible toxic effects of the level of sewage-derived material present in sediments from the influent creeks, however the results of this study indicate that further research is needed in this area.

3.3 Phytoplankton Production

The Port Phillip Bay sediments all contained a range of marine-derived sterol and fatty acid biomarkers that can be used to determine the distribution and abundance of phytoplankton. Differences in the relative levels of sterols between samples can indicate changes in community structure of source organisms (e.g. Volkman 1986) and differences in absolute amounts indicate variations in phytoplankton productivity. The various algal biomarkers in sediments of Port Phillip Bay were more evenly distributed at the majority of sites than the sewage biomarkers, however, increases in phytoplankton productivity are evident in those zones where sewage pollution is occurring.

The NSN (non-saponifiable neutrals) profiles of the Port Phillip Bay sediments were dominated by sterols such as cholest 5-en-3β-ol, 24-methylcholesta-5,22E-dien-3β-ol, cholesta-5,22E-dien-3β-ol, 24-methylcholesta-5,24(28)-dien-3β-ol, and 24-ethylcholest-5-en-3b-ol. These sterols are typical of those found in most marine sediments around Australia. Other unusual components such as diols and long-chain alkenones were also present in the sediments from Port Phillip Bay (Figure 3).

The TEFA and PLFA profiles were characterised by high proportions of 16:0, 16:1ω7c, 18:0, 18:1ω9*c*, 14:0, 20:5ω3, 20:4ω6 and 22:6ω3 (Figures 4 and 6). Such distributions are typical of largely eukaryotic aerobic communities. The polyunsaturated fatty acid 20:5ω3 and other PUFA are generally found in eukaryotic algae (e.g. diatoms, dinoflagellates and other classes) and are absent in prokaryotic micro-organisms. Variations were observed between and within zones in the relative abundance of many of the major fatty acids such as 16:1ω7*c*, 20:5ω3, 22:6ω3. Such changes are most probably the result of differing contributions of major algal classes between sites and/or zones. The high concentrations of these markers indicate that microalgae are the major source of organic carbon in Port Phillip Bay.

3.3.1 Diatoms

Sterols such as 24-methylcholesta-5,22E-dien-3β-ol, cholesta-5,22E-dien-3β-ol and 24-methylcholesta-5,24(28)-dien-3β-ol are found in many species of diatoms (Patterson 1991) and were the dominant sterols in most of the Port Phillip Bay sediments and water-column samples taken from the influent creeks. The concentration of 24-methylcholesta-5,22E-dien-3β-ol based on TOM was evenly distributed throughout the Bay except for 5 or 6 sites which had significantly higher concentrations, suggesting increased diatom productivity relative to secondary production or detrital deposition (Figure 11). These sites corresponded to sites impacted with sewage, based on coprostanol concentration data.

The ratio of 16:1ω7c relative to 16:0 ranges between 0.9 and 5.0 for many diatoms (Dunstan et al. 1994) with a mean value of about 2. Consequently if diatoms totally dominate primary production in Port Phillip Bay the ratio of 16:1ω7c relative to 16:0 would be about 2 or greater. However the ratio in the Port Phillip Bay sediments ranges between 0.4 and 1.8 which suggests there must be significant input from non-diatom algal groups. Eicosapentaenoic acid (20:5ω3) is also found in diatoms, although other algal groups can contain this fatty acid. The higher concentrations of 20:5ω3 relative to 22:6ω3 in sediment from many sites throughout the Bay also suggest that diatoms are a major source of organic matter within the Bay.

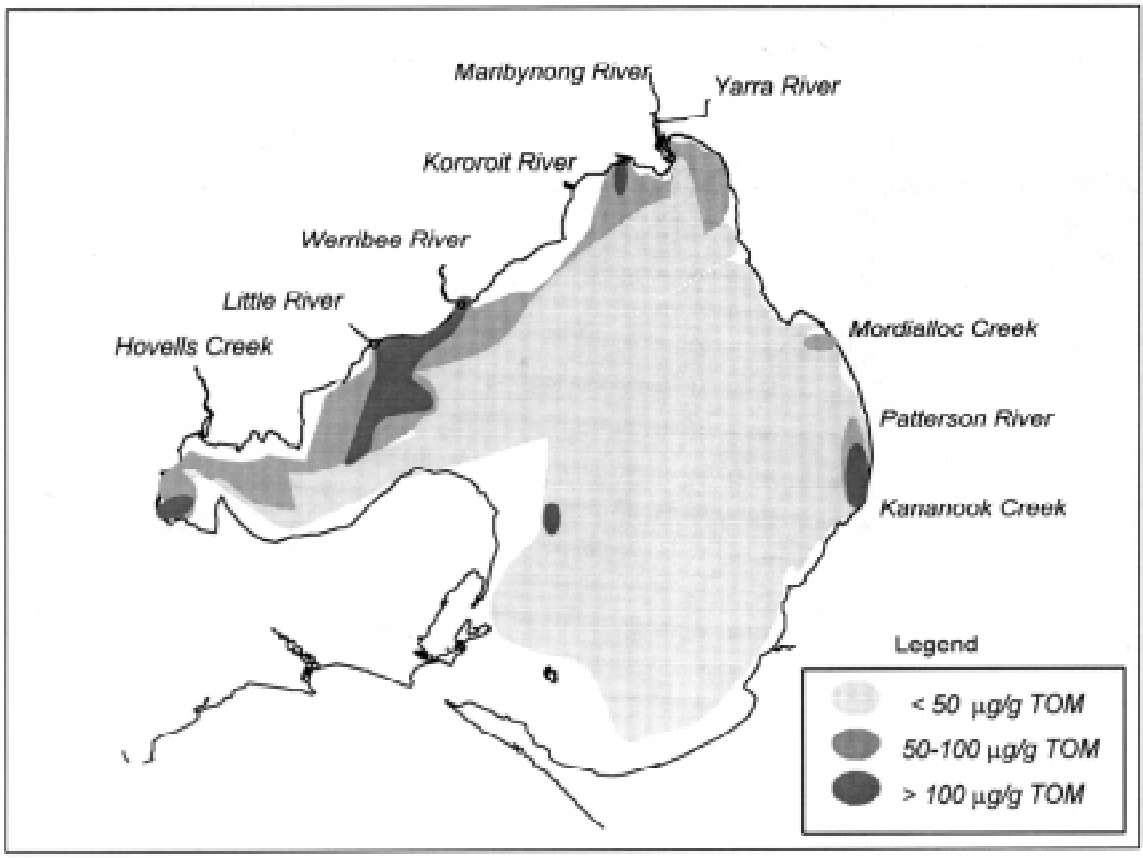

Figure 11. Distribution of a diatom biomarker (24-methylcholesta-5,22E-dien-3β-ol) relative to total organic matter in Port Phillip Bay sediments. This distribution pattern suggests that diatom input is highest (relative to other primary producers) in sediment from the creeks and the Werribee Zone.

Diatom blooms have been noted in Port Phillip Bay in 1987, 1991, 1993 and 1994. In recent years there has been concern about the occurrence of blooms of the diatom *Rhizosolenia chunii* which has been implicated as the origin of the bitter taste in mussels which feed on the alga (Parry et al. 1989). We have examined the lipid composition of a closely related species *Rhizosolenia setigera* and discovered a number of unusual compounds which may prove to be useful markers for this genus of diatom (Volkman et al. 1994). The major sterol in *R. setigera* is cholesta-5,24-dien-3β-ol (unpublished data) which is very uncommon in microalgae and only found as a very minor sterol in marine animals. Cholesta-5,24-dien-3β-ol was found in all of the sediment samples (Table 2), and at some sites (#38, #27, #20, #2 and #13) it was unusually abundant (5.4-14.9%). Its high abundance in the sediments from Werribee River (14.9%) is particularly noteworthy. Analyses of the 1994 *Rhizosolenia* bloom are underway which will result in further investigation of these markers.

R. setigera also contains an unusual suite of C_{30} highly branched isoprenoid alkenes (Volkman et al. 1994). Hydrocarbons in Port Phillip Bay are being analysed by the Victorian EPA and we are liaising with them to see if these alkenes might be present in their samples. In previous work we have identified high concentrations of these alkenes in mussels and sediment from Corio Bay (Volkman and Murray unpublished data), which suggests these unique biomarkers would be very useful for studying the distribution of *Rhizosolenia* and for tracing its contribution to marine food chains in the Bay.

3.3.2 Dinoflagellates

Dinosterol is the principal sterol associated with dinoflagellates, however there are several species which do not contain dinosterol (Patterson 1991). One such species is *Noctiluca milialis* (Teshima et al. 1980). Blooms of a closely related species *Noctiluca scintillans* have recently been recorded in Port Phillip Bay. The most abundant sterol in *Noctiluca milialis* is 24-methylcholesta-5,22E-dien-3β-ol (Teshima et al. 1980) which is one of the key sterols found in diatoms. It is possible that *Noctiluca scintillans* has a similar profile, but without a detailed study it would be difficult to determine the contribution this dinoflagellate makes to the organic matter in Port Phillip Bay sediments.

Concentrations of dinosterol indicated that dinoflagellate input relative to other sources is greater near the creeks and in Corio Bay and the Werribee Zone (Figure 12). The sterol content of dinoflagellates is considerably greater than for diatoms and other algal groups. The ratio of sterols to fatty acids in dinoflagellates is about 5 to 25 times greater than in diatoms. This feature combined with the low relative (0.9-5 %) and absolute level (20-3600 ng g^{-1}) of dinosterol present in Port Phillip Bay sediments indicates that dinoflagellates that contain dinosterol, whilst present, were not major contributors to the organic matter in Bay sediments at the time of sampling. However, dinoflagellates contain the 22:6ω3 fatty acid which suggests that the increased concentrations of 22:6ω3 noted in Hobsons Bay and the Central Zone could be derived from this dinoflagellate.

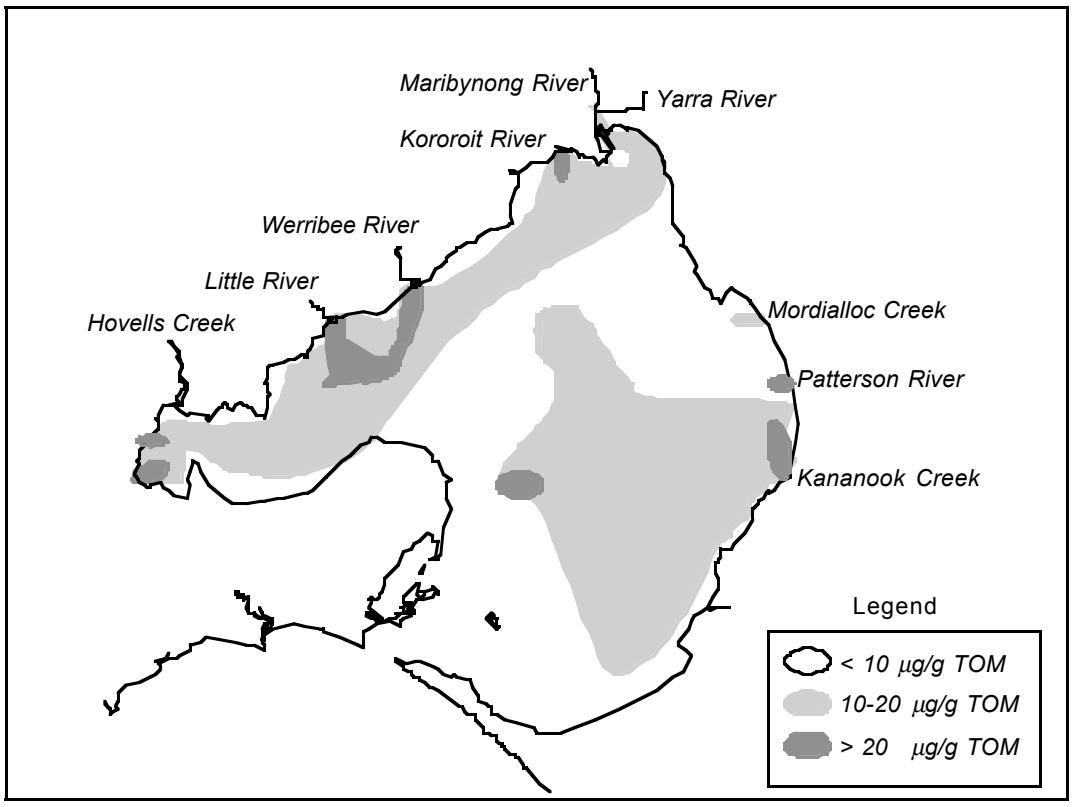

Figure 12. Distribution of the dinoflagellate biomarker, dinosterol, relative to total organic matter in Port Phillip Bay sediments. Dinoflagellate input is higher in the creeks, Werribee Zone and Corio Bay relative to other areas in Port Phillip Bay.

Blooms of toxic species of dinoflagellates have been observed in recent times in various estuaries and embayments in Australia. Blooms of dinoflagellates have been recorded in 1988, 1991, 1992 and 1994 in Port Phillip Bay. The dinoflagellate *Noctiluca scintillans* has bloomed in the centre of the Bay this year. Biomarker analyses of sediment cores at such locations would provide direct information on the relative and absolute contribution of this ecologically important algal group.

3.3.3 Other Microalgae

The wide range of sterols found in the sediments of Port Phillip Bay is consistent with a variety of algal sources which include prymnesiophytes (also indicated by the presence of characteristic long-chain alkenones), cryptomonads and eustigmatophytes.

Long-chain alkenones, which are found in some prymnesiophytes, are most abundant in the sediments from the centre of the Bay. These long-chain alkenones can account for up to 13% of the lipid from prymnesiophytes (Volkman et al. 1989). This feature combined with the low concentrations in the sediment (Table 3) suggests that this algal group is only a minor contributor to the productivity in Port Phillip Bay. The long-chain alkenones were not detected in the sediment and water-column from most of the influent rivers and creeks. This distribution pattern suggests that the prymnesiophytes are more indicative of an open marine system (Figure 13).

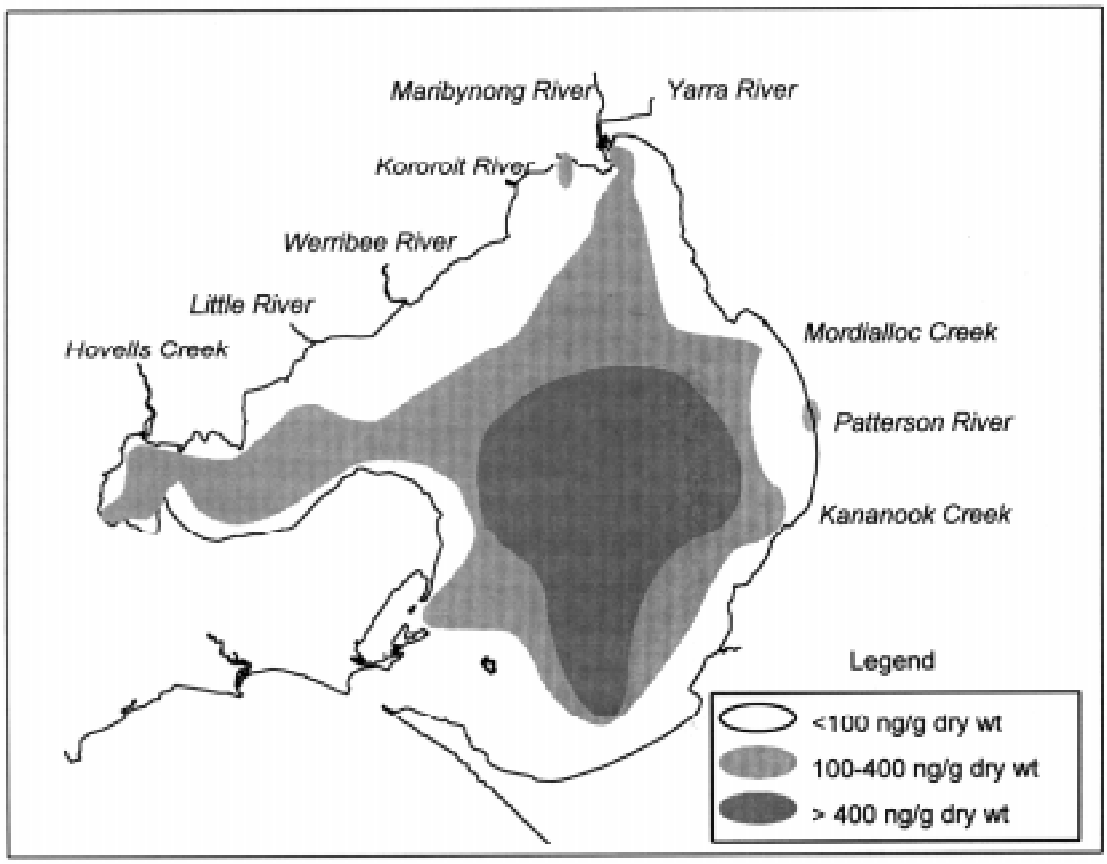

Figure 13. The distribution of long-chain alkenones, which are biomarkers for prymnesiophytes, shows higher abundance in the Central Zone.

Evidence for eustigmatophytes is the presence of an unusual C_{28} alkyl-1,15-diol which elutes near 24-ethylcholesterol on the gas chromatograms of extracts from sediments from Corio Bay, Hobsons Bay and the Central Zone. We are not aware of any report of this compound occurring so abundantly in a contemporary sediment, but structurally analogous C_{30} and C_{32} diols are quite common and have also been found in eustigmatophytes of the genus *Nannochloropsis* (Volkman et al. 1992) where they are major components. The ratio of sterols to diols in various strains of *Nannochloropsis* ranges between 2.3 and 3.7 (Volkman et al. 1992). The low concentrations in the sediments (Table 3) relative to sterols (< 0.04) suggests that the contributing microalgae are only minor constituents of the total biomass in Port Phillip Bay. The highest concentrations of diols occur in Corio Bay, Hobsons Bay and the Central Zone (Table 3).

3.4 Bacteria

The branched-chain fatty acids are biomarkers for bacteria, although they are found in most marine animals in low amounts. The relative levels of the bacterial-derived branched fatty acids (*i* and *a* 15:0 and 17:0) in both the TEFA and PLFA fractions varied by an order of magnitude between samples and was generally considerably higher in sediments from the Central Zone and the western side of Hobsons Bay. High proportions of the general bacterial markers, including 18:1ω7*c* and cyclopropane fatty acids which are common to anaerobic microbes, were observed in sediments from Central Zone sites. Bacterial input is greater in the Central Zone where the highest levels of organic material are found (based on TOM concentrations).

3.4.1 Sulfate Reducing Bacteria

Two specific markers for bacteria are 10Me16:0 and *i*17:1ω7*c*. These two fatty acids are markers for sulfate reducing bacteria (SRB); 10Me16:0 is a marker for the genus *Desulfobacter* and *i*17:1ω7c is a marker for the genus *Desulfovibrio*. Based on the relative amount observed for these two fatty acids in Port Phillip Bay sediments and the knowledge that each fatty acid accounts for approximately 20-30% respectively of the cellular fatty acids in members from the two genera, members of *Desulfobacter* genus are the more important of these two SRB groups and are present at higher abundance in Bay sediments. These biomarkers are also more abundant in the Central Zone and are present at increased abundance in some smaller pockets around the Bay. The concentration of 10Me16:0 derived from sulfate reducing bacteria is about 1% in typical marine sediments and such levels were observed at sites adjacent to the Werribee Treatment Plant. Based on TEFA and PLFA compositional data, Bay sediments are generally not considered highly anoxic. The greatest abundance of sulfate reducing bacteria, an indicator of the degree of anoxia, occurs once again in sediments in the Central Zone as previously noted.

One further feature was noted in comparing the relative proportions of 10Me16:0 and *i*17:1ω7c in both the TEFA and PLFA fractions. As noted above, at most sites 10Me16:0 was more abundant than *i*17:1ω7*c*. In contrast the TEFA fractions of creek sediments, with the exception of site #14, contained significantly higher relative levels of *i*17:1ω7*c*, the marker for lactate-utilising SRB, *Desulfovibrio.* Viable SRB populations as shown by the PLFA composition indicate that *Desulfobacter* is dominant or at least in equal proportions with *Desulfovibrio* in the Bay sediments.

3.5 Ciliates

Tetrahymanol is the principal sterol associated with bacterivorous marine ciliates (Harvey and McManus 1991). It is a conservative membrane component of ciliates from the class *Oligohymenphorea* which includes the freshwater ciliate *Tetrahymena* and the bacterivorous scuticociliates. Tetrahymanol has not been detected in herbivorous ciliates which can obtain sterols from their diet.

Concentrations of tetrahymanol ranged between 0 and 190 ng g^{-1} dry wt (Table 3). Scuticociliates contain between 0.1 and 3.0 ng of tetrahymanol per cell. This suggests that the sediments of Port Phillip Bay contain, at most, 2000 cells g^{-1}. Overall concentrations indicate that the bacterivorous ciliates were most abundant in the Central Zone sediments of Port Phillip Bay and showed a similar distribution pattern to bacteria (Figure 14).

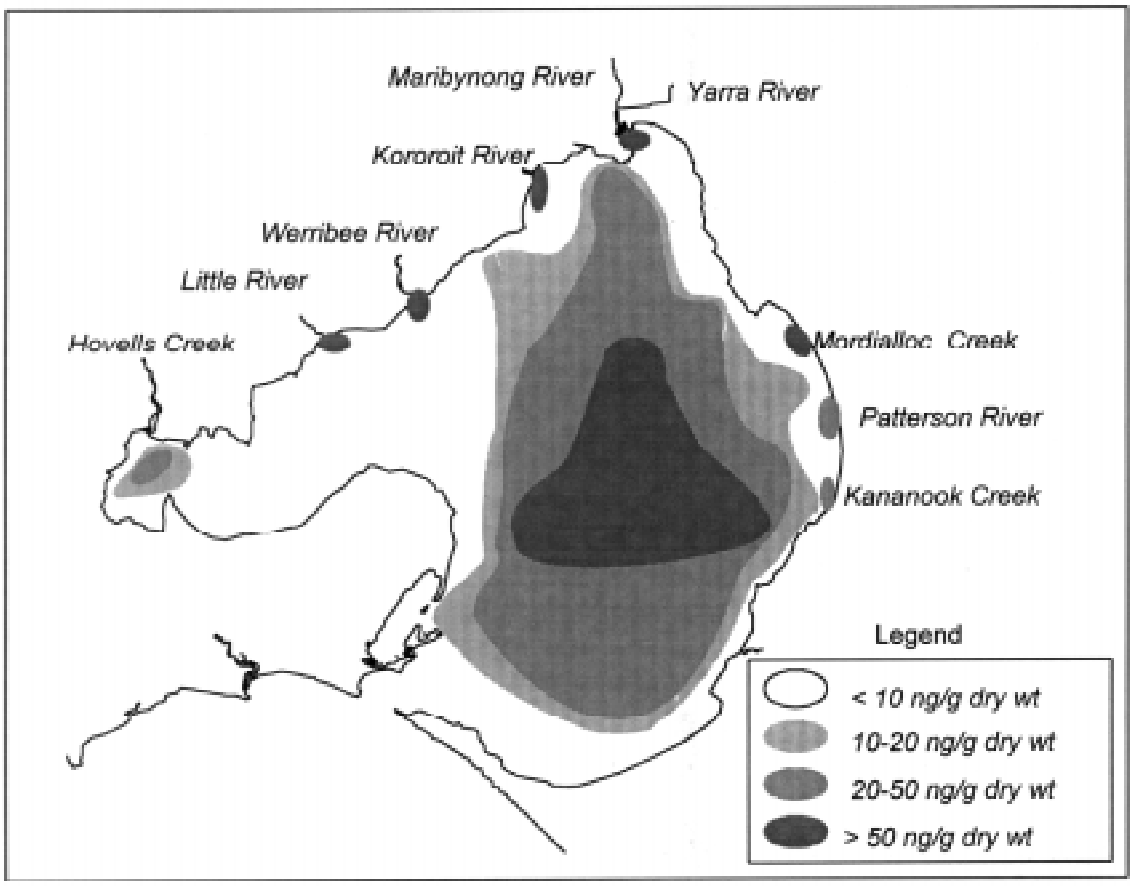

Figure 14. Distribution of the tetrahymanol, a biomarker for bacterivorous ciliates. The highest concentrations are found in the Central Zone in a similar pattern to bacterial markers.

3.6 Terrestrial Plant Inputs

Land plant material does not appear to be a major source of carbon in Port Phillip Bay sediments. This finding is based primarily on the distribution and abundance of 24-ethylcholesterol and long-chain fatty acids which are principal constituents of higher plants.

24-Ethylcholesterol is ubiquitous in marine sediments, being also a component of most eukaryotic algae. The absolute and TOM normalised concentrations of 24-ethylcholesterol in the sediments from within the Bay are proportionally no greater, perhaps even a little less, than corresponding concentrations of cholesta-5,22E-dien-3β-ol, 24-methylcholesta-5,22E-dien-3β-ol and dinosterol. However, in the influent creek water-column and sediment samples, where there is a large input of terrestrial plant matter, the sterol profile is dominated by 24-ethylcholesterol (10-46% of total sterols).

Long-chain fatty acids (24:0 to 32:0, even-carbon predominating) are also generally considered to be biomarkers for terrestrial plant matter. In the Port Phillip Bay sediments long-chain fatty acids only accounted for up to 1.5% of the TEFA. The elevated levels of long-chain fatty acids in sediment from these creeks indicate that they are possible sources of minor amounts of terrestrial matter to Port Phillip Bay.

The Central Zone is a sink for the terrestrial input that does reach the Bay, based on the presence of higher relative levels of the long-chain fatty acids when compared to sediments from other zones within the Bay. Where terrestrial plant input is significant in other aquatic environments, these long-chain fatty acids account for more than 30% of the TEFA. Therefore, based on lipid compositional data, material of terrestrial origin is not a major source of organic matter in these sediments.

4.0 CONCLUSIONS AND RECOMMENDATIONS

Selected lipid biomarker concentrations and the organic matter content for sediments from 46 sites within Port Phillip Bay and sediment and water samples from some of the creeks surrounding the Bay were determined. Sources of organic matter to the Bay include the creeks. Sinks are observed in the Central Zone and the Geelong Arm southwest of the Melbourne Water Werribee Treatment Plant (WTP), including Corio Bay. Sinks for the sewage derived organic matter appeared to be in the southwest regions of the Bay (Werribee and Corio Bay). Further investigation to confirm the source of faecal pollution in Corio Bay is recommended.

High concentrations of the faecal biomarker coprostanol were observed in most sediments from the rivers and creeks and at sites adjacent to the WTP. In particular the results obtained for isolated spot sampling in the creeks point to the generally high degree of faecal contamination in these environments, especially Mordialloc Creek. In addition, high concentrations of markers indicative of ecologically significant algal groups (e.g. diatoms and dinoflagellates) were found at the same locations. These results suggest that the creeks may be possible sources for the seeding of localised blooms in the Bay, although evidence for this is still weak. The spatial resolution of the sampling program for Port Phillip Bay sediment was not sufficient to determine transport paths in the regions immediately adjacent to major inputs such as WTP, the Yarra River and the creek mouths. We recommend that closer sampling be performed adjacent to the mouth of the Yarra River and within the plume, to measure the possible effects of elevated inputs into the Bay from this source.

The overall distribution of fatty acid and sterol biomarkers indicated that terrestrial input was minor in Port Phillip Bay sediments with the major source of organic carbon coming from marine primary producers. Biomarkers for diatoms dominated both the sterol and fatty fractions. Biomarkers for dinoflagellates, prymnesiophytes and eustigmatophytes were also present in lower concentrations. Although diatoms and dinoflagellates are clearly important bloom species, the role and importance of the nano- and pico-plankton is still poorly understood.

The highest abundance of bacterial derived biomarkers occurred in the sediments from the Central Zone. Markers for specific sulfate reducing bacteria were also more abundant in Central Zone sediments, however the absolute concentrations were low. *Desulfobacter* appears to be the more important of the two sulfate reducing bacteria groups detected. The concentration of SRB biomarkers in the top 1 cm is elevated compared to typical marine sediments. The Bay sediments are oxic at the surface and becoming reducing within 2 cm. It would be valuable to extend our work to include SRB biomarkers with depth.

To better understand the complex relationships between the physics, chemistry and biology of Port Phillip Bay it would be useful, when other data are available and accessible in the future, to relate the biomarker measurements to other parameters such as nutrient and toxicant concentration and to predicted circulation patterns under different scenarios. Further work will be required to study inputs to the Bay by collecting water column samples during normal conditions and flood events. Similarly, further work will be required to study temporal and historical (through analysis of sedimentary cores) variations in biomarker concentrations to be able to pinpoint past algal blooms and therefore the abundance of the various sources of organic carbon.

5.0 ACKNOWLEDGEMENTS

This work was funded by the Port Phillip Environmental Study and CSIRO Division of Oceanography. We thank Andy Longmore, Geoff Nicholson, the team of divers and the Master of the *Melita* from the Victorian Fisheries Research Institute, Queenscliff, Victoria who collected the sediments analysed for this report. We would also like to thank Andy Revill, who went out of his way to collect the sediment samples from VFRI and to deliver them to Hobart still frozen, and Katie Harrison for her assistance during sample analysis and data collation.

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